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PHYSICAL SECTION.

Stated Meeting, held Wednesday, May 22, 1901.

A SYSTEM OF CORRECTIONS FOR HEAT LOSSES IN CALORIMETRIC EXPERIMENTS.

BY JOSEPH W. RICHARDS,
Member of the Institute.

In 1892, the writer, conjointly with Prof. B. W. Frazier, began experiments in the metallurgical laboratory of the Lehigh University, having for their object the determination of the specific heat of copper at high temperatures, in order to render it reliably available as a substitute for platinum in pyrometry, by the method of mixtures.

To this end, the amounts of heat given out by copper and platinum from various temperatures were measured, using a copper and a platinum ball in each experiment, and then, using Violle's formula for the mean specific heat of platinum, the temperature of the experiment was calculated and thence the mean specific heat of the copper from that

temperature. The final result obtained for the specific heat of copper was

$$\text{Sm } (0 \text{ to } t^0) = 0{\cdot}09393 + 0{\cdot}00001778\ t.$$

By the aid of this formula, copper becomes available for pyrometry for temperatures nearly to its melting point, say to 1000° C. or even to 1050°, with a degree of accuracy quite sufficient for most technical purposes.

In the conduct of these experiments, the need was felt of a better system of corrections for the heat lost to the calorimeter during the experiment. The calculation of the water-value of calorimeter from the weights and known specific heats of its various parts is evidently an unsatisfactory approximation only, for heat is conducted unequally fast to the various parts because of their varying conductivity, some parts (as the thermometer stem) are partly inside and partly outside the calorimeter; and, finally, the very instant that the body of the calorimeter begins to rise in temperature ever so little, it begins also to radiate heat to its envelope—and these radiation losses are evidently not only functions of the rise of temperature, like the water-value of the calorimeter body, but also functions of the time. The corrections for heat losses during an experiment are therefore inherently time functions, being properly expressed for a given calorimeter, as so many calories at the end of 1, 2, 3, 4, 5, 10, etc., minutes after starting, per degree rise of temperature at that time, above the starting temperature.

The calorimeters used in this laboratory are of three sizes, consisting of an inner vessel of brass, covered with paper, and resting on three wooden props, contained in a walnut casing, the interspace being filled with cotton wadding. They were patterned after the calorimeters used by Andree and Ackerman, in their experiments on iron and blast-furnace slags, and fully described with illustrations, in the *Jernkontoret's Annalen*, 1884, p. 73, and 1886, p. 1. Since the systems of corrections to be described in this paper are applicable to any form of calorimeter whatever, working on the principle of mixtures, the particular kind of calorimeters

in which it was worked out is of secondary importance, and if further details are desired, reference is made to the above journal.

Our method of determining the water-values of our calorimeters for 1, 2, 3, etc., minutes after starting is purely *experimental*, and the method of procedure finally settled on is as follows: The calorimeter is taken empty and placed in a cool room, kept at a constant temperature. The stirrer is operated from time to time, and readings taken until it is seen that the temperature is constant to within say 0·01° in five or ten minutes. In an adjoining room, kept at a higher temperature, is a can of water provided with a stirrer, an accurate thermometer which has been previously compared with the thermometer in the calorimeter, and an outlet beneath with a stop-cock. This water being at a steady temperature, or very nearly so, the experiment can be made. The final temperature of the empty calorimeter is taken, it is carried to the next room, and filled with the water at the known higher temperature. The time of *beginning* the filling is accurately noted, also the temperature of the water just before running in. The calorimeter is then stoppered, carried back, stirred and readings taken at exactly at 1, 2, 3, 4, 5, 10, 15, 20, 25 and 30 minutes after the filling was started, the temperature of the room being kept as nearly constant as possible. This procedure, taken altogether, represents exactly the manner in which actual experiments with the calorimeter are afterwards carried out, and therefore the heat losses obtained from this running in of water into the empty calorimeter will represent exactly the heat losses in an actual experiment.

The data obtained will be as follows:

(1) The temperature of the empty calorimeter (t_0).

(2) The temperature of the warm water run in (T).

(3) The observed temperatures at 1, 2, 3, etc., minutes after (t_1, t_2, t_3, etc.).

The calculations will be as follows:

(4) The warm water has fallen from T° to t_1, t_2, t_3, etc., giving up

in 1 minute $W \times (T - t_1)$ calories.
" 2 minutes $W \times (T - t_2)$ " etc.

We thus know accurately the total number of calories lost to the calorimeter at the end of 1, 2, 3, etc., minutes.

(5) The body of the calorimeter has risen, meanwhile, from t_0 to t_1, etc., having thus been heated through

in 1 minute $= (t_1 - t_0)°$
" 2 minutes $= (t_2 - t_0)°$ etc.

(6) Dividing the total calories lost to the calorimeter in the first minute, as obtained in (4), by the rise in temperature of the body of the calorimeter above its starting temperature as obtained in (5), the quotient is the heat lost to the calorimeter at the end of one minute, per degree rise of the calorimeter above its starting temperature; or we might call it briefly "the water-value of the calorimeter *for one minute*." Similar calculations give us its water-value to the end of 2, 3, 4, 5, etc., minutes from starting.

These values represent all losses of every kind, and allow also for the heating up caused by stirring or the proximity of the operator; in fact, it is only necessary to determine these corrections, repeating exactly the conditions of an experiment, in order to have a practically perfect system of corrections.

EXAMPLE.

Water used . . . = 245·2 grams.
Temperature . . = 23·69¼, Geissler thermometer.
= 23·23¼, Baudin " (used in calorimeter.)

Time.	Calorimeter.					
4'55	15° 21	(Temperature of room, 18·5°.)				
'57	'22	} Rising at 0°·00½ per minute.				
'58½	'22¾					
'59	18°·23	Fall of Water.	Calories Lost.	Apparent Rise.	Corrected Rise.	Water Value Per 1° Rise.
1 minute	22° 87	0° 36¼	88·9	4°·64	4·63½	19·2 Calories
2 "	·77	0° 46¼	113·4	4°·54	4·53	25·0 "
3 "	·71	0°·52¼	128·1	4°·48	4·46½	28·7 "
4 "	·68	0° 55¼	135·5	4°·45	4·43	30·6 "
5 "	·64½	0° 58¾	144·9	4° 41½	4·39	32·8 "

A number of such experiments were made on each calorimeter, using widely different ranges of temperature; the calculations showed that the heat losses up to any given time were proportional to the range, within the experimental errors. Thus, for example, the two-minute correction determined in differing experiments was

	Calories per 1° rise.
With a range of 2°·10	28
" " " " 2°·95	27
" " " " 6°·57	27·7
" " " " 7°·18	26·8
" " " " 9°·96	26·8
2′ correction finally adopted	27·0

The method of using the corrections thus obtained is susceptible of several variations; we found the following to be the most satisfactory:

An experiment being made (in pyrometry, for instance, with a copper ball) and the readings taken at 1, 2, 3, etc., minutes after immersion of the ball, these readings are first corrected for the previous rate of rise or fall of the calorimeter. The corrected readings, minus the temperature before immersion, give the corrected rise of temperature to the end of the different minutes. The calories lost to the calorimeter to the end of any given minute is the correction for that minute multiplied by the corrected rise at the end of that minute. The heat still left in the calorimeter is, of course, the weight of water multiplied by the corrected rise. The sum of these two quantities gives the total heat given up to the calorimeter by the copper ball, when cooling to the temperature it has at the end of the given minute. But this is inconvenient, because the heat values thus obtained from readings for the different minutes are not strictly comparable, since the copper ball is at different temperatures at the end of each minute.

A more satisfactory method of using the corrections is to calculate by their aid *the theoretical temperature which the mixture (water plus copper) would have had if no heat at all had been lost to the calorimeter.* To do this, we reason that if the

heat lost to the calorimeter had not been lost, it would have raised the temperature of the water and copper a certain amount higher than it actually went. The number of calories lost to the calorimeter to the end of any given minute is therefore calculated, as before, and then this quantity is divided by the water value of the water and copper together. The number of degrees thus obtained, added to the rise of temperature which actually occurred at the close of that minute, gives us theoretically the rise of temperature which would have occurred had *no* heat been lost to the calorimeter. This is then the theoretical temperature of the mixture at zero minutes, with no losses of heat. But, every observation made, when thus reduced, gives us theoretically the *same* temperature, *i. e.*, the theoretical rise, and we have therefore as many experimental values of this quantity as we have taken observations; every observation gives us a value for this quantity, whether taken at one minute or at thirty. Slight variations in the values thus obtained are inevitable, but the fullest opportunity is thus afforded to discuss the observations and to deduce from them the most probable value of the theoretical rise. The one-minute reading, when copper is immersed, is usually identical with the later readings; but, when platinum is used this reading gives a lower corrected value than the subsequent ones, because the platinum has not yet given out all its heat, in the one minute. A still poorer conductor, like fire-clay, does not become equalized in temperature for several minutes, and the theoretical rise will be observed to increase gradually for those minutes, to become *constant* thereafter, when the clay has given out all its heat. If the outside temperature changes during the experiment, the theoretical rise will gradually increase or diminish with increasing time; in such cases, the later readings can be discarded; or, in an extreme case, the earliest reliable or constant readings alone taken.

The following illustration of the method of using these corrections is taken from an actual experiment made in the open air in the yard of the Bethlehem Steel Company, to determine the temperature of the gases escaping from flues

of boilers attached to a blast-furnace. A copper ball was put into an iron box on the end of an iron rod, inserted twenty-seven minutes in the chimney flue, then withdrawn and dropped immediately into the calorimeter.

Weight of copper cylinder	21·803 grams.
" " water used	301·80 "
Water value of copper cylinder	2·06 "
Calorific capacity of water and copper	303·86 "

Record.

5·13 = copper put into the flue.

	Calorimeter.	Rise per minute.	
5·30	16°·63	0°·02	Average 0°·019
·35	16°·73		
·40	·82	0°·018	

5·40¼ **16·825** (calculated)—Cylinder introduced.

·41¼	21·62	Corrected for previous rate of rise.	21·601
·42¼	·56		·522
·43¼	·53		·473
·44¼	·51¼		·441
·45¼	·50		·405

CALCULATIONS.

Minutes.		Rise.	Corrections.	Theoretical Range.	
0	16·825				
1	21·601	4·776	0·324	5·100	
2	21·522	4·697	0·413	5·110	Average 5·105
3	21·473	4·648	0·454	5·102	
4	21·441	4·616	0·486	5·102	
5	21·405	4·580	0·530	5·110	

The corrections were made as follows:

Water Value of Calorimeter.		Rise Above Starting.		Calories Lost to Calorimeter.		Water Value of Water + Copper.		Correction.
1′ . . . 20·6	×	4·776	=	98·39	÷	303·86	=	0°·324
2′ . . . 26·7	×	4·697	=	125·41	÷	"	=	0°·413
3′ . . . 29·7	×	4·648	=	138·05	÷	"	=	0°·454
4′ . . . 32·0	×	4·616	=	147·71	÷	"	=	0°·486
5′ . . . 35·2	×	4·580	=	161·22	÷	"	=	0°·530

Theoretical rise	5°·105
Starting temperature	16°·825
Theoretical end temperature	21°·930
Calories given out to this temperature = 301·8 × 5·105 =	1540·69
Equal to, per gram of copper	70·665
Add heat in 1 gram of copper from 0° to 21°·93	2·07
Heat in copper, 0° to t =	**72·735** Calories

Hence

$$0{\cdot}09393\,t + 0{\cdot}00001778t^2 = 72{\cdot}735$$

and

$$t = 685{\cdot}{}^\circ5$$

This experiment has been quoted in full, as it explains not only the method of making the corrections, and of using copper as a pyrometric material, but it also shows the accuracy of the system of corrections under trying circumstances. The calorimeter was rising at the comparatively rapid rate of two-hundredths of a degree per minute, and readings of the thermometer were estimated to the nearest quarter of a hundredth, but these were not very certain, yet the five corrected readings have an extreme variation of only one hundredth (0·2 per cent.) and the extreme variation from the mean was only half an hundredth (0·1 per cent.). It is very likely that the heat in the copper as it entered the calorimeter was determined to 0·1 per cent.

Experiments in the laboratory under more favorable conditions as regards external temperature and steadiness of the calorimeter have given still closer results. A score of experiments could be quoted where the maximum variation between the various corrected readings was under 0·1 per cent. I quote a few to show particularly that the corrections apply as accurately to high ranges as to low ones:

2′			1°·885	6°·111	7°·417	
3′			1°·888	6°·122	7°·416	7°·779
4′		1°·221	1°·888	6°·123	7°·416	7°·785
5′		1°·222	1°·888	6°·122	7°·416	7°·781
6′	0°·540	1°·222				
7′	0°·541	1°·221				
8′	0°·541					
9′	0°·542					
10′	0°·542					

The last one given is particularly interesting, in that it was a reversed experiment, in which ice was put into the calorimeter and its temperature fell 7°. The corrections for the flow of heat *into* the water, were made by the same method, using the heat losses as determined experimentally for heat flowing *out of* the water and although the correc-

tions applied footed up 0°·676 to 0°·782, yet the corrected values agree to 0°·006, or 0·1 per cent. of the total rise.

In conclusion, we express our conviction, based on several years' work with this system of corrections, that they enable the experimenter to measure the heat brought into his calorimeter with an accuracy equal to the precision with which he can read his thermometer; that is to say, the errors in the corrections will be within the possible errors of reading the thermometer. In the case of our calorimeters, the Baudin thermometers are graduated in fiftieths of a degree, and we estimate the quarter-hundredths, (although these are not certain) yet the various corrected readings usually check up within one-half an hundredth of their mean value, and often within the quarter hundredth.

It has also been found by experience that our students readily master the method of using the system and enjoy the satisfaction of obtaining accurate and satisfactory results in this rather difficult experimental field.

METALLURGICAL LABORATORY,
LEHIGH UNIVERSITY, May 23, 1901.

TECHNICAL BREVITIES.

——In a British patent issued to Herr Kugel, of Berlin, is described a method of *depositing nickel electrolytically* in layers of such thickness that the product is equivalent to rolled nickel in its mechanical properties of toughness, durability and ductility. The method is to acidify the nickel solution with a mineral acid which is unalterable by the electric current. Such an addition usually spoils the bath, causing the deposit to flake off, but this difficulty is overcome by keeping the electrolyte at a temperature over 30 degrees centigrade. Under these circumstances a homogeneous non-crystalline metal is said to be deposited and may be put down in sheets of any required thickness.

——An Austrian patent granted to Herr C. Kellner, of Vienna, is claimed to disclose a process whereby extraordinary light-efficiency is secured with *incandescent lamp filaments*. The filament may be made by two methods. In the first, the thread is made, under great pressure, of the powder of an infusible metal such as thorium, which is then oxidized superficially by making it the anode in an oxidizing electrolyte bath. It is stated that the layer of oxide adheres strongly to the metal. The second method is to form the threads from metallic oxides which have the property of becoming incandes-

Hence

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cent at comparatively low temperaturers and using as a cementing material the least possible amount of cellulose dissolved in chloride of zinc. Upon the p ssage of the current it is stated to become very compact, resembling graphite.

——The Germans have invented *a new description of glassware*, specimens of which have been on exhibition in England. This cloisonné glass, as it is called, is similar to stained glass, but is claimed to be superior. The design is prepared in double brass wires, and the interstices are filled with small pieces of colored glass. This design is then mounted upon a large sheet of plain glass, to which it is firmly attached by means of a translucent cement. Another similar sheet of glass is then placed upon the top of the design in the same way, so that the colored glass is inserted between two sheets of glass. By this means the cloisonné glass is smooth on either side. It cannot be bent or loosened, and in view of the thinness of the brass wires more light is admitted than is the case with stained glass, owing to the thickness of the leaden framework in the latter.

——Messrs. Walsh Brothers, of Janvier, N. J., have successfully reproduced the celebrated *aventurine glass*, heretofore made exclusively in Venice. They have also devised a method whereby the product can be formed into large masses of any desired form, thus adapting it for use in decorative work such as tiling, panelling, table-tops, mantlepieces, inlaid work, etc. A superb collection of specimens of this new product was made at one of the recent meetings of the Franklin Institute.

——*Celluloid* has heretofore been manufactured by dissolving nitrocellulose in camphor—that is to say, forming a mixture of nitrocellulose, camphor and alcohol. But there are other ways of mixing it. According to a publication of the Société Générale pour la fabrication des matières plastiques de Paris, celluloid can be made by using naphthalene instead of camphor. The celluloid thus produced, the paper adds, is just as good as, if not better than that in which camphor forms one of the ingredients.

——The state of California has appropriated $250,000 to purchase and preserve the grove of *redwoods* near Santa Cruz. This excellent work was accomplished largely through the agency of a body of Californians especially organized for the purpose, called the Sempervirens Society. The area purchased is unfortunately not very large, and the finest redwoods are found further north. Several thousand acres of land will be purchased in the neighborhood of Humboldt Bay, running from the ocean back across the summit of the coast range. Two or three millions of dollars would be sufficient to make the entire purchase, and the Government would do well to preserve this wonderful collection of forest trees for all time. W.

Mechanical and Engineering Section.

Stated Meeting, held Thursday, March 14, 1901.

THE AUTOMATIC GUN AND ITS MILITARY ASPECTS.

By Cecil Hamelin Taylor.

(*Concluded from p. 12.*)

Existing examples of automatic guns may be divided into two main types:

(1) Those operated by the energy of recoil, and,

(2) Those in which the gases of explosion act to operate the mechanism in any other way than to produce recoil.

Type 1 may again be divided into three classes, according to their cycles of operation.

A. In which the action opens during recoil, and closes during counter-recoil.

B. In which during the recoil, nothing is done but storing energy, which is used to return the barrel to battery, and thereby to open the action and subsequently to close it.

C. In which the energy of recoil is stored during recoil and used to return the barrel, the mechanism opening fully as the barrel reaches the half-way position, and closing as the barrel gets fully home.

The cycle of class *A*, invented by H. S. Maxim, seems to offer greater possibilities than those of either class *B* or class *C*. All else being equal it can be made to operate more rapidly, with fewer parts and more positively, than can examples of the other two classes, and it lacks but one feature possessed by either of the others; namely, tardy extraction.

The importance of tardy extraction has been magnified by those interested in guns possessing the feature, but from my own experience, I believe it negligible for any arm smaller than the three-pounder, and I attach little weight to it. The claim has been made that the cartridge-case,

being in contact with the gases of explosion, becomes so much expanded by heat that it is difficult to extract until somewhat cooled; and that the metal wall being thin and in contact with the cooler metal of the barrel, it loses sufficient heat in a small fraction of a second to greatly decrease the difficulty of extraction.

In small arm practice this theoretical advantage is negligible. The most widely known example of class *A* is the commercial Maxim machine gun. The construction and operation of this gun is roughly, as follows:

A toggle-joint connects the breech-block to the recoiling frame which carries the barrel, in such a way that the straightening of the toggle closes and locks the breech. The rear link of the toggle is an arm of a bell-crank, so designed, that after a certain distance has been travelled by the barrel and frame in its recoil, the other arm of the crank is rotated by striking a stationary abutment. The toggle is thus bent and the breech unlocked and opened. A single spring is placed so as to resist both the recoiling motion of the frame and the opening motion of the breech, and this spring returns the two pieces independently of each other. The feed may be described as a vertically sliding cartridge clip carried by the block, and it acts as extractor, face-plate and ejector also. In the firing position it is in its uppermost position, and the top engages the head of the cartridge in the belt, which is fed through the gun just over the chamber. At its lower end it engages the head of the case in the chamber. During the opening of the breech the feed remains in the same vertical position, but slides to the rear with the block, extracting one cartridge from the belt and the other from the chamber. At the full-open position the feeder drops down, bringing the live cartridge opposite the chamber and the empty case opposite the ejector opening, below the chamber. The block then advances, inserting the cartridges in their respective cavities. At the end of the closing motion the feeder is quickly moved vertically upward to engage another cartridge in the belt, during which movement it retains its grip on the case in the chamber, but drops the fired case in the

ejector opening. The lock mechanism is in no way original and deserves no notice.

In but few examples of class *A* do we find incorporated the feature which it is possible to obtain in its best form in this class of arm only, and which should therefore be one of the strongest features of arms of this class. I refer to the advantage to be obtained by connecting the block to the barrel by rigid double acting mechanism, that is, mechanism acting to move the block positively by a movement in either direction of the barrel. In the Maxim and the Borchardt this condition is one-half fulfilled by single-action connectors, giving us the advantage of increased energy for extraction, but little for insertion.

The class *B* or "Counter-Recoil" gun was first patented in 1891 by R. M. Catlin, an American mining engineer. It presents the sole advantage of allowing a longer time between explosion and extraction for the case to cool and contract, facilitating extraction. This is counter-balanced by the fact that the available energy for starting extraction is less than in the class *A* arm, owing to the slow speed and small energy of movement of the barrel at the start of the counter-recoil when the extraction takes place. This energy of movement and the tension of the recoil spring are the only forces available for extraction. As above stated, the advantage of time for cooling before extraction is of little importance in small arms, and for ordnance, high speed is of such paramount importance that this time cannot be allowed.

The inherent disadvantages of the class are slowness, weak operation, and the necessity of using some form of catch. It is possible this last objection may be eliminated from these guns, but until this is done, the presence of a catch is objectionable. This is principally owing to the practical difficulties of manufacture, tempering, etc., and to the irregular results of rust and dirt on the action of the catch. A spring is also usually necessary to operate it. During a wide experience with guns of this type I have had more difficulty with the catch than with all other parts of the gun together.

No examples of class *B* have been put on the market, but a number have been constructed. The Catlin-Carr gun has, I believe, been acquired by the Driggs-Seabury Gun and Ammunition Company, and F. M. Garland of New Haven has constructed a number of models of various calibers,—so far with but small success. The rate of fire is only about one-half that of similar guns of the previous class.

Class *C* was first patented in 1894, by Armand Meig, a German inventor. It cannot compete with class *A* in speed, but it is faster than the Catlin cycle. The principal disadvantage is the excessive speed of the breech parts, unless the counter-recoil movement of the barrel be checked. If this be done, energy is wasted, and the rate of fire diminished. The strains on the mechanism are great and partake of the nature of blows, thus requiring heavier mechanism, or reducing its life. A form of catch is common to this class, as well as the former.

We now come to type 2, in which the gas pressure acts to operate the mechanism without recoiling the barrel. This type may be subdivided into the following classes:

D. In which the fermeture is supported elastically so as to be moved by the breech-pressure on its face.

E. In which the barrel is allowed to move forward away from a stationary breech, by the friction of the ball in the bore, etc.

F. In which the gas acts in various ways after exhausting from the muzzle.

G. In which a vent leads the gases under pressure from the bore behind the projectile to the point of mechanical application.

Class *D* I term the "Piston-block" variety. It was first patented in England in 1854, by Henry Bessemer.

In order to store sufficient energy in the moving parts it is necessary that the movement of the block under pressure be greater than a certain minimum, and it has been found with this minimum that the cases were very frequently burst and the piece jammed. This results from the following action: At the instant of explosion the case is expanded tightly against the chamber walls, and at the same time

driven backwards against the fermeture. If this support be elastic it gives, and allows the head of the case to move rearwardly under the pressure. The walls of the case being pressed against the chamber-wall by many tons pressure cannot move to the rear, and the head tears itself loose from the case body which remains in the chamber as a lining, preventing the introduction of a new cartridge.

To eliminate the difficulty Maxim designed a case with ring-corrugations near the head, which were intended to give sufficient stretch to the case to allow of the heads moving to the rear without tearing the metal. This method has not given satisfaction, and even had it done so, the necessity of using a special ammunition is a grave objection to the arm for rifle caliber use. Baron von Mannlicher has also worked in this direction, but with little encouragement. The most successful example is the "Browning" pistol made in Belgium.

In spite of the grave practical objections against this class of arm, it is theoretically the most rapid in its operation, owing to the lightness of the moving parts and to the absence of lost movements. Practically, however, the necessary resistance to motion of the fermeture must be obtained either by giving it great weight and bulk, as does Maxim, or by depending upon friction, as does Mannlicher. The last method gives more irregular results, and has failed entirely.

Class *E*, in which the barrel moves forward by the friction of the shot in the bore, and the pressure of the powder gas against the front of chamber, was first patented in this country in 1892 by Raphael Mallén. The advantages of the system are those of compactness and simplicity, and for this reason various modifications have been patented in the form of pistols by Burgess, Mannlicher, Wesson and others, the Mannlicher weapon having been produced commercially.

The class may be considered as merely a modification of class *D*, in which, in order to add weight to the movable piston-block, the latter has been made integral with the stock. This will illustrate the most serious fault of the design—that of excessive recoil—for the grip or stock is

really the recoiling piece, which being lighter that the whole gun recoils more violently than would the gun if rigidly constructed, as is the modern hand repeater. One of the primary advantages of the recoil automatic systems is that of reducing the recoil by distributing the shock over a period of time. Guns of class *E*, on the other hand, not only fail to reduce recoil, but actually greatly increase it. The fault of premature extraction, simultaneous with the combustion, is common to this class, as well as the former, though the probability of failure is somewhat reduced, owing to the lesser distance travelled under pressure by the heavier breech-piece. The increase in recoil peculiar to this class gives little promise of its future efficiency.

Under class *F* must be placed the many devices designed to utilize the gases of exhaust to operate the mechanism of the piece. There are two general methods for doing this: By utilizing the impact of the gas stream and by utilizing the expensive force of the escaping gas. The difference may be said to be that between the action of steam in a turbine and in a piston cylinder.

The impact devices may be again divided into direct acting or inducing, depending upon whether the gas-jet acts directly against the mechanism or acts by inducing a partial vacuum or air current, which operates the action.

Indirect or inducing impact devices should be advantageous from the consideration of the erosive effect of the heated products of explosion in the direct-acting type, but the loss of energy involved in its transfer to the induced currents is a serious drawback. A combination of the two methods seems to promise well, since the induced current can be mixed with the gas-jet and thus cool it and at the same time increase its volume and lower its velocity, increasing the convertible energy and decreasing erosive effect.

The expansion method theoretically gives the best results, but it has to contend with the practical difficulties of making gas-tight joints which will not foul by powder-residue or allow erosion to interfere with its workings. The absence of these objections gives the impact devices a de-

cided advantage over those operated by expansion. The muzzle-exhaust system seems to be little suited to small-arm conditions, but for machine guns and quick-firing artillery it promises well. Extreme clumsiness and slight inaccuracy, due to the confined exhaust, are the chief weaknesses of the existing examples of the class among which may be mentioned McClean's and Maxim's inventions.

Class G, in which the gases escape from the barrel through a vent and act partially before the projectile has left the bore, has much in common with the last type. It may be divided into the same sub-divisions and the same general mechanisms may be employed to utilize the gas energy, whether the exhaust be from the muzzle or through a vent. The disadvantages are the same, except that the inaccuracy is reduced, though it is still somewhat disturbed by the presence of the vent and the irregularities of pressure arising from it.

The best known examples of this class are the Colt guns, used in the U. S. Navy, and the Hotchkiss, which is still in a more or less experimental state.

The Colt gun operates by the gases acting against a plug carried by a swinging lever or pendulum. Sufficient energy is imparted to the pendulum to cause it to swing through an arc of about 180° against a spring tension which operates to swing it home again. During the swing rearwardly the action is opened, and during the forward return home the action is closed and locked. The method of mounting the piston on a lever to reduce friction is excellent in itself, but the transverse forces resulting from the violent swinging and pounding of the pendulum and the reaction of the operating gases is very disturbing to the aim, and is a serious defect. Were the pendulums mounted in pairs symmetrically, much of this would be avoided and the arm greatly improved. Difficulty of feeding out of the belt has been experienced in this arm, but this is entirely due to defective detail, and though vital, yet should be easily remedied and does not come within our scope of investigation.

The Hotchkiss gun is fundamentally a single-acting

steam engine in which a spring serves to return the stroke, and where the bullet in the bore is the admission valve. Though simple in construction, it is heavy and easily clogged. The prestige of the company, whose name it bears, may suffice to make it more or less successful, but past tests have not shown it to be highly efficient, and but little can be done to improve it.

I conclude from all the above that the best examples of the automatic gun will be of the recoil class *A*, and that this is true for all sizes of arms, from the pistol to the quick-firing gun. Next to this I place the exhaust operated class *F*, after which the vent operated class *G*, then in the order named classes *C*, *B*, *E* and *D*, and it is in this order in which I expect to find them fifteen years from now, when the automatic gun will have emerged from the experimental state.

THE BALLISTIC PROPERTIES of automatic arms for military purposes are equal in importance to structural considerations of the mechanism.

The fundamental problem of service of the automatic gun on land, is that of the ammunition supply. With a rifle calibre machine gun firing continuously at the rate of about 600 shots per minute, the weight of ammunition consumed in one minute's firing is about thirty-five pounds, whence the importance of keeping the weight of ammunition as low per unit of effect as possible. The problem for the designer thus reduces itself to finding the minimum limit of power which the gun should have and to obtaining the minimum weight cartridge to give this power. To solve this question it is necessary to understand the tactical value and meaning of the automatic gun in warfare.

The advantages for military use of an automatic repeating shoulder arm, with combination magazine and belt feed, over the present magazine hand repeater are manifold. Foremost among these is that of rapidity with accuracy. The limit of semi-aimed rapidity of fire is about a shot a second with the best of the modern repeaters, though the action can be operated at about double this rate. The diffi-

culty lies, then, not so much in operating quickly, as in regaining aim after the recoil and the disturbance necessary for operation. The most efficient automatic arm must be one in which the recoil effect upon the shooter will be reduced to a minimum, and in which the mechanical moments of the operating mechanism will be exerted in a longitudinal direction. Having a given weight of weapon, we can thus either increase the ballistic energy or decrease the recoil, or, to a less extent, do both. Having the cartridge given, the arm may be lightened and the recoil reduced. This might be effected more simply in the hand repeater by the use of a spring recoil check, without making the piece automatic; but except for the general value of reducing recoil for single shots, it would add little to the value of the arm as a repeater, since with the necessity of executing the operating motions before the next shot, the recoil of the first shot has little effect on the aim of the second. In the automatic arm, on the other hand, the only disturbing effect on the second shot is entirely due to the recoil from the first. By minimizing this recoil we obtain the maximum efficiency both as a repeater and as a single shot arm.

It is true that the problem of ammunition supply is so difficult that it becomes important not only to be able to prevent more rapid firing than is now possible, but frequently even to compel slower fire. It is a generally accepted opinion that during the greater part of an action the rate of fire should not exceed four shots per man per minute. It appears, however, from experiment that doubling the rate of fire increases the effect in a given time by about one and one-half times, and on this the accepted values of fire-rates are based. Metcalfe gives the following table of rates of fire with a magazine gun and their effects;

Rate.	Shots per minute.	Effect.
"Common,"	6	1·0
"Rapid,"	12	1·5
"Magazine,"	24	2·25

It is the opinion of every civilian and military rifleman without exception with whom I have discussed the matter,

that this slow rise in effect of rapid fire is due to the disturbing influence on the aim and attention of the motions required to reload the arm, and that with the automatic system an effect of about 9·0 in the above scale could readily be obtained firing at the rate of sixty shots per minute with a belt feed, with which no leading motions need be executed by the shooter. Not only do I agree with this general conclusion, but I believe that with a skilled operator the *efficiency* will *rise* as the rate of fire increases after a certain point is passed. I believe this will result from the effect on the morale and from the results of the fire being made more apparent to the operator, allowing him to more quickly and accurately adjust for range. Particularly will this rise be noticeable in shooting from the prone positions, while from the standing positions a slight drop in efficiency may be expected.

Neglecting the above conclusions entirely, as lacking practical proof, I conclude from *accepted values* that the automatic arm must supersede the hand repeater by virtue of the fact that the rate of fire can be much more than doubled with it, or the effect in a given time can be increased to over 3·38, as against 2·25 for the magazine arm. This alone is sufficient to make its introduction certain. Objectors may argue the difficulty of controlling fire, and the rarity of the demand for the highest rate of fire, as it was argued against the magazine arm ten years ago, but so long as *concentration of effort* remains the chief factor on the battlefield, the answer will be that fire *must* be controlled; but controlled or not, the arm allowing the greatest concentration of fire in respect to time, as well as space, all else being equal, will be the most efficient arm. The problem will then be that of supply, and, generally speaking, the army having the most perfect mechanism for ammunition transport and distribution will be the victor.

Apart from this cardinal advantage of the automatic type, it presents that of allowing of better concealment, no motions which might betray the shooters' presence being required for operation. In the hands of exceptionally skilled men and fitted with telescope sights, it would make a most for-

midable weapon for picking off the enemy's officers whenever exposed, as well as for quickly plotting ranges in advance of artillery.

In describing the fire effect of crank machine guns—the prototype of the automatic gun—at Alexandria, in 1882, Lord Beresford said that, in his opinion, "machine guns, if properly handled, would decide the fate of a campaign, and would be equally useful ashore or afloat."

Prof. W. L. Cathcart, in a recent article, says:

"The place of the machine gun in the attack seems still undetermined. It is unquestionably an aid to infantry in close fighting, since, under such escort, a constant fire can be maintained. Again, in high-angle firing a hail-storm of bullets can be rained upon the heads of men behind entrenchments. Its effectiveness in defense, however, is beyond a doubt. Nothing can equal it in stopping the rush of desperate men, or in reinforcing the fire of infantry. The place of the arm, therefore, is essentially in the reserve as a gun of position."

Capt. Henry Metcalfe, in his "Ordnance and Gunnery," the text-book used at West Point, says: "Owing to the desire to simplify the supply of ammunition machine guns are frequently fitted to the cartridge used by infantry. * * * Their ballistic properties restrict their scope to the zone of infantry fire, within which their value consists in the small number of men required for their service and the consequent possibility of selecting the coolest and most skillful men and of protecting them from the enemy's fire. The difficulties of transportation on land appear to assign this class to the defense, for which service the concentration of its fire upon objects hidden by their own smoke renders it most valuable. * * * Compared with ordinary field artillery the range and power of the infantry ammunition is so limited, the correction of the aim so difficult, the moral effect of solid projectiles so small, that machine guns of small caliber, though rendered popular by their great mechanical efficiency, will probably in service be relegated to subordinate purposes of the defense, and for use against an enemy unprovided with artillery.

"When compared with infantry operating in open or wooded ground their deficient mobility would often render them an obstruction rather than a help; since only under exceptional circumstances can they maintain their own defense.

"Owing to the suddenness with which, in order to produce a decisive effect, their services are required it has been proposed to attach them to small tactical units of infantry and cavalry; but the objections above cited and the evident difficulty of administrating such scattered commands would probably cause this plan to fail. * * *

"The transport of the large amount of ammunition that machine guns require compels the use of wheeled draught (except in mountain service) and therefore assigns them to the artillery. The question then arises, whether, having a given supply of men, horses and money, these means may not better be utilized in the legitimate sphere of the artillery, rather than in providing a defensive arm of only occasional utility. * * * For naval purposes, where difficulties of supply hardly exist, their value is greater."

We see that the rifle caliber machine gun as constructed until now is deficient in mobility and in vulnerability compared to infantry, and deficient in range and shock, compared to artillery. It is superior to infantry in accuracy and concentration of fire, and to artillery in mobility. Our effort, then, must be directed toward increasing these advantages and minimizing these unfavorable features.

The first question—that of mobility—includes the considerations of portability, mobility proper, and the ease and speed with which the piece on the march may be put in readiness to fire.

There are two mountings for machine guns—the tripod or stand mount, and the wheeled carriage. With the first the piece must be carried bodily when changing position, while in the second it is drawn. A minimum total weight for gun and stand of about 35 pounds has been imposed upon the tripod mounting by the necessity for steadiness in overcoming recoil.

In these mounts a saddle is attached to one leg of the

tripod, upon which the operator sits, thus adding a fraction of his own weight to that of the piece. By a tripod, on the fore legs of which the operator might rest his feet while sitting on the rear leg, the operator's entire weight would be applied at a more efficient center of effort than in the former case. By this means the restrictions as to minimum weight, imposed by recoil, may be entirely eliminated, and the lightest piece becomes the most efficient. A water jacket has very generally been applied to this type of arm, under the impression that long-continued firing would frequently be required. With a heavy weapon mounted on the wheel carriage, and thus having but slight mobility, continued fire will doubtless be required, as the gun will not be used from a precarious or temporary position, but will be reserved for use at more or less protected semi-permanent points where continued fire will be demanded. With a weapon, however, weighing say 15 pounds complete with stand, adapted to be handled by one man and used either as a shoulder arm or on its tripod, and to be set up, from the packed position, on its tripod to begin firing within 15 seconds of the word of command, and as quickly repacked, continuous fire for over 100 shots would seldom be required. With the modern infantry ammunition, a barrel without a water jacket may be fired 600 times within the minute without serious injury to the bore, so that in exceptional circumstances automatic continuous fire could be maintained for a considerable period with such a gun.

At the point where a piece ceases to become easily portable and operable by one man, it becomes, in fact, artillery, and at once loses its mobility to a great extent. Thus a gun weighing 15 pounds could be handled in the skirmish line, if so desired, but a 40-pound gun would be of little use there, and would be but slightly more mobile than one weighing 140 pounds. If, therefore, we wish to construct a gun much heavier than the infantry rifle, for continuous fire, with a water jacket, and elevating and traversing mechanism which has been found most important for such work, the gun will be mounted most efficiently for military purposes, on a wheeled carriage. Once mounted on wheels,

slight additions of weight are no longer vitally objectionable. The arm may, therefore, be more freely adapted to the various functions it may be called upon to perform.

The ballistic demands of such a gun are these: The effective range should exceed by at least 1500 yards that of the infantry arm against which it may be used; the ball should be of sufficient weight to inflict severe wounds on horses when high angle fire is used; the penetration should be at least one and one-half times that of the infantry arm, in order to force the enemy to throw up heavier entrenchments, or to reach him behind those of standard profile and to drive him from the face of wooded ground. This penetration would be ample to pierce at moderate ranges, the $\frac{1}{8}$ and $\frac{1}{4}$-inch plates at present used to protect the personnel of machine guns, and would thus necessitate the use of heavier armor, decreasing the enemy's mobility. The complete piece should be composed of not over four, easily separable elements, of a maximum individual weight of 40 pounds, so that it could be used as a mountain gun, and if necessary carried by men.

These considerations, together with those of minimum weight of gun and ammunition, can best be combined in a gun of about caliber ·38-inch, firing a mantled bullet of about 500 grains weight, with a velocity of about 2500 feet second. The gun body would weigh between 30 and 40 pounds, the trail and wheels each about the same. The ammunition would weigh about nine rounds to the pound, so that 300 rounds could be carried by one man. If a shield were added it would be in two pieces, each weighing less than 40 pounds, though for mountain service it would seldom be required.

It will be seen that such a gun has an almost limitless sphere of utility. It can be used in the attack at ranges at which only artillery can be brought against it and its mobility is such that it may avoid to a great extent the effects of artillery fire. The power of the arm would be sufficient to greatly facilitate picking up ranges, as the effect of impact will be much more readily detected than that of infantry ammunition. It may be possible even to construct

a special non-explosive range-finding shot to indicate the point of impact still more clearly. As a light mountain gun, ground is accessible to it to which no other weapon than the infantry rifle could be brought, and from such a position high angle or direct fire simulating with its 500 shots per minute, the effect of shrapnel could be maintained to a radius of 5,000 yards. This function would be equally valuable whether in the attack or defence. Even as a high angle gun on level ground, it could deliver its fire at a distance safe from infantry fire interference.

For naval-landing purposes such a gun is ideal, being of a size easily handled from a launch and of sufficient range to clear a landing without danger from infantry fire to the personnel. The penetration, speed and flatness of trajectory make it a formidable weapon, even against torpedo boats, though for this purpose it will, undoubtedly, be found inferior to the full caliber gun.

Full-caliber automatic guns, unlike the smaller sizes, cannot do double service. Naval conditions demand flat trajectory, penetration and rapidity of fire more forcibly than they demand large mine power or great range, whereas army conditions reverse these requirements. First comes range and mine-power, and then in the order named, rapidity of fire, penetration, and trajectory. The mobility of field guns gives rise to the problem of checking any movement of the carriage due to the recoil.

Considering these conditions carefully, I conclude that for naval use a gun of about caliber 1.25 inch, firing one-pounder shot containing about 200 grains bursting charge with a velocity of about 3,000 feet seconds would give the best results. This gun would give a trajectory so flat that within the range of about 1,500 yards no change of sight would be required to keep on a target the size of a torpedo boat, bow on. This question of uniform elevation within critical ranges is a vital consideration for torpedo-boat destroying guns, and sufficient weight does not yet seem to have been given it. The penetration would be ample to completely pierce any torpedo destroyer even with forward transverse bunker protection, yet built; while the mine-

powder is just sufficient to cause fragmentation. The rate of fire could be over 300 shots per minute. The mounting should have accurate worm elevating mechanism not adapted to be thrown out of register, and coarser mechanical traverse which can be thrown in and out quickly to allow of freely swinging the piece when necessary to quickly change the aim. A shield of at least ¼ inch thickness should be carried on the mount as a protection against machine gun fire. This gun would alternate well with a semi-automatic six or nine pounder. I think it doubtful that guns heavier than the three-pounder will be made purely automatic.

For army service the conditions call for a gun of about caliber 1.56 inch, throwing a long shell, somewhat tapered at both ends, weighing about three pounds, and containing about a 1,000 grains bursting charge, with about 2,000 feet seconds velocity. Such an arm would be as small and light as possible, consistent with a range nearly equal to that of field artillery, mine-powder sufficient to be effective against houses and light field fortifications, and the use of an effective canister. The fact that for a given weight of discharge per minute small canister is more effective than large against troops at critical ranges, owing to the possibility of its more perfect distribution, makes such a gun more nearly self-protecting than field artillery proper. It should be mounted on a mountain high-angle-fire carriage, and, if expected to be exposed to infantry fire, a shield should be applied. Mechanical elevating and traversing mechanism, which can readily be thrown out of gear, should be fitted.

My conclusions on the requirements of automatic guns lead me to believe that some such system as the following will be ultimately adopted by the great armaments of the world.

The infantry rifle will be a recoil automatic of class *A*, weighing only about 6½ pounds, and designed to be operated as a single loader, magazine gun and belt feeder. A simple method of attaching to a tripod weighing not over 5 pounds will be provided, the gun being used either from the shoulder or stand as desired. The arrangement will be such that the

arm complete may be carried in a compact holster, with the tripod if required, and be capable of being set up and fired within ten or fifteen seconds from the command, and as quickly repacked. The present infantry ammunition, with slightly increased power, will be retained. This arm will also replace the cavalry carbine.

The small caliber machine gun will use a cartridge of about caliber ·38 on the general lines of the infantry ammunition. This arm will have a water jacket or other cooling device, and will be mounted on a wheeled carriage, with or without a shield. It will be made in various constructions, but the recoil types (those of class *A* and classes *F* and *G*) will be most successful. The arm will be handled as a unit, as well as in battery, and attached to small tactical units of infantry and cavalry, as were the "batallion guns" in the Seven Years' War. In the navy it will entirely displace the rifle caliber machine gun.

The present one pounder "pom-pom" will be generally superseded in the army by a similar gun of over double its weight, of about four times its power, and without a water jacket. This arm will be handled as a special type of artillery, and will be of wide tactical value. The general data of this piece will be about as follows;

Maximum weight of single element	250 pounds.
Weight of gun body	250 "
Weight of carriage complete	350 "
Total weight without shield	600 "
Weight of one round	4·5 "
Weight of projectiles	3 "
Muzzle velocity	2,000 feet second.
Bursting charge	1,000 grains.

In the navy we shall see a high-powered, water cooled one pounder displace the present inefficient light gun, and become one of the considerable factors in naval actions. The data of this gun will be:

Weight of gun body	200 pounds.
Weight of complete piece (with mounting)	350 "
Weight of one round	1·7 "
Weight of projectile	1· "
Muzzle velocity	3,000 feet second.

The light one pounder automatic may be retained for naval landing and other special services, but will play a subordinate rôle.

The feasibility of making guns of 6 pounds and above to operate fully automatically, is a question which cannot now be decided. It remains to be seen just what examples of the automatic and semi-automatic types will do, what the rate of fire will be, and what the various advantages and disadvantages of each type are. I am inclined to the belief that though the fully automatic larger guns will ultimately supersede those operated manually in any way, yet the immediate future will see the semi-automatic type generally adopted.

The next important step in ordnance, after the development above outlined has taken place, will be in the direction of improving the ballistics of the arms by reducing the weight of ammunition to perhaps less than one-half its present weight. This problem is one for the chemist as well as for the mechanician, and its solution will mean another great advance.

A NEW PHONOGRAPH.

A new type of phonograph, the invention of a Danish engineer, Valdemar Poulsen, was shown at the Paris Exposition. It works upon an entirely new principle, and the record, instead of being made of wax by a stylus, is made upon a steel wire by the action of a magnet. A cylinder is wound full of steel wire about one millimeter thick, the wires touching each other. In front, in a position analogous to that of the stylus, is a small electromagnet whose polar ends are brought out and are reduced to a small diameter to embrace the upper half of the steel wire. It is supported upon a horizontal rod, and the lateral motion obtained by a guide which travels between the wires. The magnet is connected with a telephone transmitter and battery, and the sound waves cause a variation in intensity of the electromagnet, and this in turn acts upon the steel wire passing before it, leaving a permanent impression. When the action is reversed, the wire reacts upon the magnet and the sound is heard in the telephone. The magnetic trace may be obliterated by passing a continuous current in the electromagnet and turning the cylinder. The apparatus was shown in the Danish exhibit; another form was shown, in which the record is made upon a thin steel band wound upon a drum.

CHEMICAL SECTION.

Stated Meeting, held Thursday, March 28, 1901.

SOME ABRIDGMENTS IN CHEMICAL CALCULATIONS.

By Prof. Joseph W. Richards,
Member of the Institute.

In calculating the volumes of gases produced from any weight of solid, liquid or gaseous substance, a few simple relations render the calculations very direct.

The molecular formula of a gas represents in an equation one volume, relatively, of that gas. The molecular weight represents, likewise, a relative weight. If, now, we call the total relative weights entering into a given reaction kilograms, then each molecule of gas represented in the equation will represent the volume of molecular weight in kilos of a gas, which, by Avogadro's law, is the same for all gases. For hydrogen this volume is

$$\frac{2}{0.09} = 22.22$$

cubic meters, and this is the volume of molecular weight in kilos of all gases. We can, therefore, say that, calling the relative weights entering into an equation kilograms, each molecule of gas in the equation represents 22.22 cubic meters of that gas.

By similar reasoning and calculation we can affirm the relations between the relative weights considered as grams, pounds or ounces, and the actual volumes thus represented in liters, cubic feet or cubic inches. We therefore have the following relations:

If relative weights be	Each molecule of gas is
Kilos	22.22 cubic meters.
Grams	22.22 liters.
Pounds	355.9 cubic feet.
Ounces	22.24 cubic feet.

(Volumes being at 0° C. and 760 millimeters.)

E. g:

In the manufacture of acetylene gas

Molecules of gas = relative volumes							1
	CaC_2	+	H_2O	=	C_2H_2	+	CaO
Relative weights	64	+	18	=	26	+	56

Whence it follows that

64 kilos	of	CaC_2	+	18 kilos	of	H^2O	produce	22·22 m^3	of C^2H^2
64 grams	"	"	+	18 grams	"	"	"	22·22 liters	of "
64 pounds	"	"	+	18 pounds	"	"	"	355·9 ft^3	of "
64 ounces	"	"	+	18 ounces	"	"	"	22·24 ft^3	of "

The most complicated of chemical equations bear the application of these simple principles in a similar manner.

To calculate quickly from the volume composition of a gas the weight of carbon, hydrogen or oxygen which it will contain in unit of volume, we need only to apply the following principles:

Equal volumes of all gases contain equal numbers of molecules; therefore, if a gas molecule of any gas whatever contains one atom of carbon, or of hydrogen, or of oxygen, we can say of such gases that equal volumes of them contain equal numbers of atoms of carbon, hydrogen or oxygen, as the case may be, and, therefore, equal weights of each of those elements respectively.

But 1 cubic meter of CO contains 0·54 kilos of carbon; therefore, that statement is true of 1 cubic meter of any other gas with one atom of carbon in its molecule, such as CO_2, CH_4, etc. Gases with two atoms of carbon in their molecule, as C^2H^6, would contain $2 \times 0{\cdot}54 = 1{\cdot}08$ kilos of carbon by the same principles, and so on to C_3H_8, etc. Carbonic oxide, CO, also contains 0·72 kilos of oxygen per cubic meter; whence a similar set of relations for CO_2, etc. Hydrogen gas, H_2, contains 0·09 kilos of hydrogen per cubic meter, whence it follows that 1 cubic meter of a gas with one atom of hydrogen in its molecule, as HCl, will contain

$$\frac{0{\cdot}09}{2} = 0{\cdot}045$$

kilos of hydrogen.

We can, therefore, state that for a gas containing in its molecular formula one atom of carbon, hydrogen or oxygen, the weights of those elements present in a given unit of volumes would be:

	Carbon.	Hydrogen.	Oxygen.
In 1 cubic meter	0·54 kilos.	0·045 kilos.	0·72 kilos.
" 1 liter	0·54 grams.	0·045 grams.	0·72 grams.
" 1 cubic foot	0·54 ounces.	0·045 ounces.	0·72 ounces.
" 1 " "	0·0337 pounds.	0·00281 pounds.	0·045 pounds.

For a gas with two atoms of carbon, hydrogen or oxygen in its molecule, the respective weights are twice the above; and so on for any gas, no matter now complicated. For practical calculations, I recommend keeping only the above constants in mind, and simply doubling or trebling the volume of the gas, instead of doubling or tripling the constant.

E. g.: Calculate the weight of carbon, hydrogen and oxygen present in 1 cubic meter and 1 cubic foot of natural gas, of the following composition;

	PER CENT. (BY VOLUME).		
CO_2	5·7	=	0·057
C_2H_4	0·9	=	0·009
CO	15·4	=	0·154
H_4	8·3	=	0·083
CH_4	3·8	=	0·038
N_2	65·9	=	0·659
	100·0		1·000

CALCULATION FOR CARBON.

CO_2	=	0·057
C_2H_4 . . . . 0·009 × 2	=	0·018
CO	=	0·154
CH_4	=	0·038
		0·267 × 0·54 = 0·1442 kilos per m^3
		0·267 × 0·0337 = 0·0090 pounds per ft^3

CALCULATION FOR HYDROGEN.

C_2H_4 . . . . 0·009 × 4	=	0·036
H_2 . . . . . 0·083 × 2	=	0·166
CH_4 . . . . . 0·038 × 4	=	0·152
		0·354 × 0·045 = 0·01593 kilos per m^3
		0·354 × 0·00281 = 0·0010 pounds per ft^3

CALCULATION FOR OXYGEN.

CO_2	0·057 × 2 =	0·114
CO	=	0.154
		0·268 × 0·72 = 0·1930 kilos per m³
		0·268 × 0·045 = 0·01206 pounds per ft³

These principles save much labor, especially in metallurgical calculations.

METALLURGICAL LABORATORY
LEHIGH UNIVERSITY, March 1, 1901.

THE ANDREW CARNEGIE RESEARCH SCHOLARSHIP.

We have received from the Secretary of the Iron and Steel Institute of Great Britain the accompanying information, issued by order of the Council of the Institute, relating to the foundation of a scholarship by Mr. Andrew Carnegie for the purpose of fostering the progress of iron and steel metallurgy by aiding the cause of original research in this branch of applied science:

"A Research Scholaship or Scholarships, of such value as may appear expedient to the Council of the Iron and Steel Institute from time to time, founded by Mr. Andrew Carnegie, Vice-President, who has presented to the Iron and Steel Institute thirty-two one-thousand dollar Pittsburgh, Bessemer and Lake Erie Railroad Company 5 per cent. Debenture Bonds for the purpose, will be awarded annually, irrespective of sex or nationality, on the recommendation of the Council of the Institute. Candidates, who must be under 35 years of age, must apply, on a special form before the end of April to the Secretary of the Institute.

"The object of this scheme of Scholarships is not to facilitate ordinary collegiate studies, but to enable students, who have passed through a college curriculum or have been trained in industrial establishments, to conduct researches in the metallurgy of iron and steel and allied subjects, with the view of aiding its advance or its application to industry. The National Physical Laboratory, on the governing body of which the Iron and Steel Institute is represented, would for many reasons be a very suitable place in which such a research could be carried out. There is, however, no restriction as to the place of research which may be selected, whether university, technical school, or works, provided it be properly equipped for the prosecution of metallurgical investigations.

"The appointment to a Scholarship shall be for one year, but the Council may at their discretion renew the Scholarship for a further period instead of proceeding to a new election. The results of the research shall be communicated to the Iron and Steel Institute in the form of a paper to be submitted to the Annual General Meeting of members, and if the Council consider the paper to be of sufficient merit, the Andrew Carnegie Gold Medal shall be awarded to its author. Should the paper in any year not be of sufficient merit, the medal will not be awarded in that year."

Further information and application blanks may be obtained by interested parties on application to Mr. Bennett H. Brough, Secretary, 28 Victoria Street, London, Eng.

W.

CHEMICAL SECTION.

Stated Meeting, held Thursday, March 28, 1901.

THE CHEMISTRY OF DEPOSITS IN STEAM BOILERS.

By W. E. RIDENOUR,
Member of the Institute.

This is a very old subject, having been worked upon by many eminent chemists on both sides of the Atlantic, and from many different views.

Some have devoted their ideas to the prevention of scale formation inside the boiler, under which heading you will find in literature and on the market at the present time as many remedies as there are patent medicines for the ailments of the human body.

Others have taken up the purification of water outside the boiler; while again others have debated as to the chemical salts existing in these deposits. With this latter subject I wish to deal this evening, in conjunction with a study of their physical appearance.

Before proceeding with these deposits, I wish to call attention to the vast amount that accumulates in a boiler from a good water for steam purposes in a month's run.

An average of several analyses of a water which is largely used in Philadelphia, the Schuylkill, is as follows (when it is clear):

	Grains Per U.S. Gallon.
Organic and volatile	5·060
Calcium sulphate	3·560
Magnesium sulphate	·602
Sodium chloride	1·167
Calcium carbonate	·357
Solids	10·746

There are 4·519 grains of scale-forming matter per gallon in this water, which, for a 1,000 horse-power plant, the average for these times, and allowing 4 gallons to be evaporated per hour per horse-power, will give the following:

4	gallons per hour per horse-power.
10	hours per day.
40	gallons per day per horse-power.
26	days per month.
1,040	gallons per month per horse-power.
1,000	horse-power.
1,040,000	gallons per month per 1,000 horse-power.
4·519	grains per gallon of scale-forming matter.
4,699 760	grains.
671	pounds of sediment per month.

The above are small figures for the average plant, as private wells are generally used, which are much worse, ranging from twenty-five to seventy-five grains per gallon; in one case in particular I recall from the soft coal district of this State, it amounted to eighty-three grains per gallon, and so situated that it had to be used.

Small wonder, then, that so many workers have been attracted to this troublesome subject.

For convenience, I have divided these accumulations into four classes, according to the predominating constituent:

(1) The calcium sulphate scales.
(2) The calcium carbonate scales.
(3) The silicate scales.
(4) The magnesia scales.

The calcium scales are, as a class, very hard and porcelain-like, examples Nos. 7 and 9, but a few are quite soft, example No. 8. They can generally be told from the others with the aid of a simple magnifier, by their glassy or vitreous appearance.

There has been some debate as to how the calcium sulphate exists, whether as a hydrate or an anhydrite.

Mr. V. B. Lewes (*Chemical News*, 1899, 59–222) states that it is first deposited as a hydrate $(CaSO_4)_2H_2O$, by coming in contact with the heated plates forms the anhydrite $CaSO_4$. I have always found it to occur as the anhydrite, $CaSO_4$, example No. 7, from South Australia:

	Per Cent.
Moisture at 100° C.	·23
Calcium sulphate	94·89
Magnesium hydrate	1·98
Silica	·25
Organic and undetermined	2·65

The calcium carbonate deposits are usually moderately soft, but the presence of even small quantities of either magnesia, calcium sulphate or silica modifies them to variable degrees of hardness, some equaling those of the first class.

Example of soft scale No. 10.

Example of hard scale No. 11.

If moderately pure they are readily recognized by the magnifier, being composed of distinct crystals, samples Nos. 10 and 15; some being easily seen by the naked eye, sample Nos. 12 and 14. This crystalline appearance is pronounced in some deposits of but 50 per cent. calcium carbonate, sample No. 14, which contains:

	Per Cent.
Calcium carbonate	51·73
Calcium sulphate	26·10
Magnesium hydrate	11·32
Silica	·42
Iron oxide and alumina	·39
Organic and undetermined	10·04

The silicate scales to me are the most strange and interesting. They are most common in the Southern States, but I have received a few from different States.

In these scales there is a combination of calcium oxide and silica, existing as calcium silicate, which, I think, is formed during the violent boiling under pressure in the boiler, by the free silicic acid, occurring in the water, reacting with the calcium carbonate.

Sample No. 2, from Louisiana:

	Per Cent.	Calcium Silicate.
Calcium carbonate	36·40	
Calcium oxide	7·32	7·32
Silica	41·00	7·84
Magnesium hydrate	·50	
Alumina	9·68	15·16
Organic and undetermined	5·10	

Sample No. 3, from New Jersey.

	Per Cent.	Calcium Silicate.
Moisture at 100° C.	4·55	
Calcium carbonate	7·47	
Magnesium hydrate	2·74	
Calcium oxide	21·94	21·54
Silica	51·07	23·50
		45·04
Calcium sulphate	1·56	
Iron oxide	1·34	
Organic and undetermined	9·33	

An extreme case is sample No. 4 from Olympia, Washington:

	Per Cent.	Calcium Silicate.
Calcium oxide	36·42	36·42
Silica	40·51	39·02
		75·44
Magnesium hydrate	3·04	
Iron oxide and alumina	2·66	
Oil	11·50	
Organic and undetermined	5·87	

Sample No. 16 from this State is especially interesting, as I was able also to get a sample of the water. The scale contained:

	Per Cent.	Calcium Silicate.
Calcium oxide	5·42	5·42
Silica	48·02	5·80
		11·22
Calcium sulphate	3·95	
Magnesium hydrate	3·58	
Iron oxide and alumina	27·08	
Organic and undetermined	11·95	

The water analyzed:

	Grains Per U. S. Gallon.
Calcium carbonate	1·311
Calcium sulphate	·104
Magnesium carbonate	1·147
Sodium chloride	·850
Silica	1·469
Organic and volatile	1·340
Solids	6·221

In comparing these two analyses, it is seen that the calcium carbonate occurring naturally in the water has completely disappeared before forming into scale, making quite possible the hypothesis that the silica has reacted with the calcium carbonate during evaporation.

The silicate scales have no characteristic physical appearance.

The magnesia scales have caused considerable disagreement among the many investigators, as to which salt of magnesium is found in these deposits, whether magnesium oxide, magnesium hydrate, or magnesium carbonate. Magnesium hydrate is now the generally accepted combination and I agree that this is the usual salt occurring.

Sample No. 5 from Texas contained:

	Per Cent.
Calcium carbonate	4·25
Calcium sulphate	7·50
Magnesium hydrate	82·95
Silica	3·10
Iron oxide and alumina	1·18
Organic and undetermined	1·02

But a few specimens have been examined by me, which contained magnesium carbonate.

Sample No. 17 from Pennsylvania.

	Per Cent.
Calcium oxide	4·39
Magnesia	59·79
Carbonic acid	22·29
Silica	5·36
Alumina	2·92
Organic and undetermined	5·25

which is equivalent to

	Per Cent.
Calcium Carbonate	7·83
Magnesia	38·23
Magnesium carbonate $(Mg.\ Co_3)_4\ Mg.\ (OH)_2$	42·25
Silica	5·36
Alumina	2·92
Organic and undetermined	3·41

It is quite possible that magnesium carbonate is first deposited from the water upon being heated, but changes

after forming into scale, in proportion to the heat to which it is exposed, into magnesium hydrate, or even magnesium oxide.

There are no marked characteristics under the glass to distinguish these deposits from the others.

It is not safe to express an opinion of a water supply, by an analysis of the usual sample of deposit taken from a steam boiler, as exclusive of the influence on the scale of the various preventives used, different portions of the same boiler form scales of quite different composition.

Samples No. 12 and 13 are from the same boiler, but are as different as if formed by a carbonate and a sulphate water.

Sample No. 12 contains 96 per cent. of calcium carbonate, while No. 13 has 76 per cent. of calcium sulphate.

This can be explained if we consider the location in the boiler from which the two samples were taken.

Scale No. 12, composed chiefly of calcium carbonate, came from near the feed-pipe, where the water first comes in contact with the heat, thereby driving off the free carbonic acid and precipitating the calcium carbonate thus held in solution; while the calcium sulphate still remains dissolved until it reaches the hottest part of the boiler, the bottom plate, where sample No. 13 collected. Mr. V. B. Lewes mentions that he examined several scales from different parts of the same boiler, all of which varied considerably.

I only wish further to call your attention to a few curious deposits on the table.

LABORATORY G. W. LORD,
PHILADELPHIA, March 28, 1901.

ESTIMATION OF HYDRATE IN THE PRESENCE OF ALKALI CARBONATE.

By W. E. RIDENOUR,
Member of the Institute.

After reviewing the several methods of estimating caustic alkali in the presence of carbonate, and carbonate in the presence of hydrate, the method proposed by R. T. Thompson appeared to be the best, if accurate.

Mr. Thompson (Sutton, Vol. Anal., Fifth Edition), weighs off a quantity of the sample to be tested, dissolves in water and titrates with standard acid, using phenolphtaline, which gives the hydrate and half of the carbonate; then, by adding methyl orange and continuing the titration, the other half of the carbonate can be found.

To test the above method, a solution of sodium carbonate C.P. was made and titrated with following results:

Sod. Carbonate Solution.	Normal Hydrochloric Acid.	Indicator.
10 c.c.	9.535	Methyl orange.
	4.574	Phenolphtaline.
10 c.c	4.985	Methyl orange.
	9.149	Phenolphtaline.
20 c.c.	9.971	Methyl orange.
	Decinormal Hydrochloric Acid.	
10 c.c.	94.78	Methyl orange.
10 c.c.	45.026	Phenolphtaline.
	49.858	Methyl orange.

Standard acid, with the factor 1.6377, was used, the sodium carbonate solution was well diluted, and the end of the burette kept below the surface of the liquid.

The indicators (U.S.P., 1890) were also tested; four drops in 100 cubic centimeters of distilled water responded at once to one drop of normal acid and alkali.

A solution of sodium hydrate, C.P., was then made and tested in the same manner.

Sod. Hydrate Solution.	Normal Hydrochloric Acid.	Indicator.
10 c.c.	11·822	Methyl orange.
10 c.c.	11·565	Phenolphtaline.
10 c.c.	·257	Methyl orange.
	11·365	Phenolphtaline.
	Decinormal Hydrochloric Acid.	
10 c.c.	2·67	Methyl orange.
	115·444	Phenolphtaline.

The above would seem to indicate the presence of carbonate in the hydrate, so barium chloride solution (W. Smith, *J. S. C. I.*, i., 85), was added to 100 cubic centimeters of sodium hydrate solution in a flask until it ceased to give a precipitate,* water added to make 200 cubic centimeters allowed to settle and the clear liquor titrated.

Clear Sodium Hydrate Solution.	Decinormal Hydrochloric Acid.	Indicator.
20 c.c.	2·57	Methyl orange.
	115.464	Phenolphtaline.

If carbonate was present then it is impossible to eliminate the same by precipitation with barium chloride solution.

Combining sodium carbonate and sodium hydrate solutions in various proportions, the following results by titration were obtained.

By comparing the different results it can be seen that phenolphtaline does not indicate half of the carbonate, either alone or in combination with hydrate, but a definite ratio is observed between the results in the titration of pure

* Produced only a slight cloudiness.

Sodium Hydrate Solution.	Sodium Carbonate Solution.	Normal Hydrochloric Acid.	Indicator.
10 c.c.	10 c.c.	16·088	Phenolphtaline.
		5·191	Methyl orange.
10 c.c.	10 c.c.	21·2796	Methyl orange.
10 c.c.	1 c.c.	11·9762	Phenolphtaline.
		·7196	Methyl orange.
10 c.c.	3 c.c.	12·9528	Phenolphtaline.
		1·6962	Methyl orange.
		Decinormal Hydrochloric Acid.	
1 c.c.	1 c.c.	15·98	Phenolphtaline.
		5·60	Methyl orange.

NOTE.—Allowance must be made in proving these results by the factor 104.5726, for the possible presence of carbonate in the sodium hydrate used.

sodium carbonate when using methyl orange alone, and using phenolphtaline followed by methyl orange.

Multiply by two the number of cubic centimeters of normal hydrochloric acid necessary to neutralize a definite quantity of pure sodium carbonate indicated by methyl orange, using phenolphtaline, then methyl orange and divide by the number of cubic centimeters of normal hydrochloric acid necessary to neutralize the same quantity of pure sodium carbonate, using methyl orange only, gives 104·5726, *i. e.*,

$$\frac{2 \times 4{\cdot}985}{9{\cdot}535} = 104{\cdot}5726$$

For figures see Table I.

Therefore, to obtain the number of cubic centimeters of normal acid corresponding to the carbonate present in a mixture of alkaline hydrate and carbonate, multiply by two the number of cubic centimeters of normal acid indicated by methyl orange, using phenolphtaline, then methyl orange and divide by the factor 104·5726.

LABORATORY OF GEO. W. LORD,
PHILADELPHIA, March 28, 1901.

VICTORIUM, A NEW ELEMENT.

Sir William Crookes has recently given an account to the Royal Society of his discovery of the new element which he calls victorium. It has a pale brown color and dissolves easily in acids. Its oxide is less basic than that of yttrium, but more so than the greater part of the earths of the terbium group. The chemical properties of victorium differ in many respects from those of yttrium, but generally speaking it may be said to occupy an intermediate position between this element and terbium. It is admitted that the oxide of victorium has the formula Ve^2O^3, its atomic weight is not far from 117. The photograph of the spectrum given by the oxide shows certain definite lines which have not been observed with any other body. The spectrum is obtained by the incandescence of the body in a vacuum tube; the light given off has been analyzed by a spectroscope of great precision and the exposure upon a photographic plate shows a series of interesting rays in the ultra-violet region. In order to examine the negative an apparatus has been constructed which will measure to the 1-100,000 inch. W.

ACTION OF RADIO-ACTIVE MATTER IN A MAGNETIC FIELD.

The *Scientific American* gives the following abstract of a communication lately presented to the French Academy by M. Becquerel giving the results of some recent experiments on the behavior of radio active matter in a magnetic field, viz.:

In the experiments previously described, the active matter contained a large proportion of the newly discovered element radium; in continuing his experiments with matter containing the other new element, polonium, discovered by M. and Madame Curie, which possesses properties analogous to the former, he finds that the action is entirely different; the radiations from this body, while showing in other respects nearly the same activity as those of radium, are not appreciably affected by the magnetic field. M Becquerel shows this conclusively in the following experiment. The preparation of polonium is placed between the poles of an electro-magnet whose intensity equals 4,000, then 10,000 c. g. s. units; above this, at distances varying from 2 to 10 millimeters, a photographic plate was disposed horizontally. This plate was not enveloped in black paper, as in the case of radium, as the rays from this body are absorbed to a considerable degree; the operation was therefore carried out in the dark. Under these conditions, after some minutes' exposure an impression is obtained upon the plate which is symmetrical with relation to the radiant source, and this impression is the same, whether the magnet is excited or not. If the preparation of radium is then substituted under the same conditions, an impression is obtained upon the plate which, under the influence of the magnetic field, is thrown over to one side as in the previous experiments. It thus appears that the radiations emitted by polonium are not influenced in the same manner as those of radium. It has been observed also that these rays are very unequally absorbed by different substances. To these observations should be added those made by M. and Mme. Curie upon the compounds of uranium, which are found to be unaffected by the magnetic field. W.

CHEMICAL SECTION.

Stated Meeting, held Thursday, May 23, 1901.

MOISSAN'S RESEARCHES ON FLUORINE AND THE FLUORINE COMPOUNDS.

By Dr. H. F. Keller,
Member of the Institute.

The student of the history of any science is constantly impressed with the great lack of symmetry in the progress of that science at the different periods of its development.

He observes that the great majority of those, who, working simultaneously, contribute to our knowledge, direct their energies toward one common goal marked out for them by certain great leaders of thought.

In chemistry, for instance, we have a number of fairly well-defined periods which derive their names from those lines of research which predominated in them. We speak of periods of pneumatic, quantitative, organic and physical chemistry, and such terms characterize quite well the main directions of chemical work during the times to which they refer.

A single province of a science may be thus explored, while others are entirely neglected.

Some of us remember the time when the current literature of our science consisted almost exclusively of organic research work, while a younger generation of chemists has witnessed the rise of another school which seeks to apply mathematical and physical methods to the solution of chemical problems, and our journals now fairly teem with publications along these lines. Where only yesterday we had heated controversies on structural formulæ, condensations, carbocyclic and heterocyclic compounds, and spacial arrangement of atoms, the words ionization, conductivity, phase rule, and the like strike our ear to-day.

But the more careful student of scientific progress cannot fail to notice also that there has always been a smaller

band of workers who, isolated from the main body, have pursued untrodden paths and among them men of genius who have enriched their science with veritable bonanzas of important discoveries.

Such pathfinders and explorers have lived in all the periods of our science, and the present generation, notwithstanding what we are told in eloquent memorial addresses, has no cause to lament them as an extinct species, so long as we can point to such men among us as Berthelot, Emil Fischer, Baeyer, Van't Hoff, Ramsay and Moissan.

And the investigations of the two last named afford ample proof that the inorganic province of our science, far from being exhausted, presents a most encouraging prospect of rich yields to come. As Moissan has so well said: "No subject is ever closed. It remains always open for our successors; we can only add a link to an infinite chain."

The subject I wish to bring before you this evening, gentlemen, are the researches of this contemporary chemist upon fluorine and the fluorine compounds.

Historical.—The process of etching on glass by means of a mixture of fluorspar and sulphuric acid, was practised more than two centuries ago by Schwankhard of Nuremberg, but the first chemical investigation of the reaction of the acid with calcium fluoride was made by Margraff, in 1768. The active product of this reaction remained unknown, however, until the year 1771, when Scheele obtained and described hydrofluoric acid, and also showed that it has a corrosive action upon glass. The Swedish chemist did not succeed in preparing hydrofluoric acid in the pure state and its preparation and properties were made the subject of study by many other chemists. The most complete investigation was made by Gay-Lussac and Thenard, in 1809. In 1813 and 1814 Sir Humphry Davy published a number of important papers on hydrofluoric acid and the fluorides, in which he showed that the acid does not contain oxygen, and that it must be regarded as an hydracid consisting of hydrogen and an unknown element, fluorine, an hypothesis which, it appears, had been suggested to him by Ampère.

To test the correctness of this view, Davy prepared the fluoride of ammonium by neutralizing pure hydrofluoric acid with pure ammonia, and strongly heated the product in a platinum still. Not a trace of moisture appeared in the cooler parts of the apparatus, while the ammonium salt was sublimed. Submitted to the same conditions the oxygen acids invariably furnished considerable quantities of water. In order to obtain more positive proof of the hypothesis, Davy endeavored to isolate from hydrofluoric acid the radical which he believed to be combined with hydrogen and to have properties similar to those of chlorine. His numerous attempts in this direction remained fruitless; neither by means of powerful electric currents, nor by the chemical action of chlorine on hydrofluoric acid and various fluorides was it possible to produce the desired effect. Davy concluded that fluorine is endowed with more energetic affinities than any other known element, but expressed the belief that the element might be isolated under conditions which he had not been able to bring about.

Although the experience of Gay-Lussac and Thenard, as well as Davy's, had demonstrated that anhydrous hydrofluoric acid is one of the most dangerous substances to experiment with, not a few chemists, after them, took up the problem of isolating fluorine from it. In their heroic attempts to solve the problem, some of these experimenters suffered severely, and Louyet even paid with his life for his devotion to science.

A great deal of valuable knowledge concerning the fluorine compounds was accumulated in this way, especially by the work of Fremy and Gore, but the preparation of the element in the free state had not been achieved in 1884, when Moissan began those beautiful experimental researches of which it is my desire to give you a brief acccount.

(1) *Various Attempts to Isolate Fluorine.*—After carefully studying the extended literature on the subject, Moissan tried in four different ways to effect the isolation of fluorine. On three of them he met with no success, but the fourth led him triumphantly to his goal.

These attempts comprise experiments on:

(*a*) The action of the electric-spark discharge upon certain gaseous fluorides, such as those of silicon, phosphorus, arsenic and boron.

(*b*) The action of incandescent platinum upon the fluorides of phosphorus, and the fluoride of silicon.

(*c*) The electrolysis of arsenic trifluoride, and

(*d*) The electrolysis of hydrofluoric acid.

Considerable space is alotted in Moissan's book to the description and discussion of the numerous and varied experiments by which the first three methods were put to test, but, although they brought to light many new and interesting facts, we may dismiss them with the author's

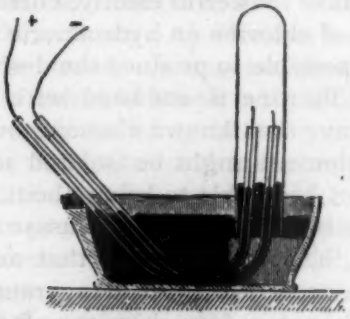


FIG. 1.—Apparatus employed in submitting silicon fluoride to the action of the induction spark. The dry gas is collected over mercury in a glass vessel and sparks are passed between the terminals of the platinum wires which are surrounded by the curved glass tubes containing mercury. No indication of any decomposition was observed even when the sparking was long continued.

words concluding that part: "These studies did not give me free fluorine, but furnished invaluable information on the electrolysis of liquid fluorine compounds; they trained me in this delicate mode of experimenting, and finally led me to the decomposition of anhydrous hydrofluoric acid."

(*Figs. 1, 2* and *3* illustrate the apparatus used in these experiments.)

The apparatus used for the electrolysis of arsenic fluoride was not adapted to that of hydrofluoric acid. The latter consisting of two gaseous elements, it was essential to separate these the moment they were set free. A U-shaped

platinum tube was therefore used, the ends of which were closed with cork stoppers soaked in paraffin which held and insulated the platinum rods serving as electrodes. Just beneath each stopper a small branch tube was attached to the limbs of the U-tube, to permit the gaseous products to escape from the vessel. To prevent volatilization of the hydrofluoric acid (it boils at 19·5°), the apparatus was immersed in a bath of methyl chloride. This liquid boils

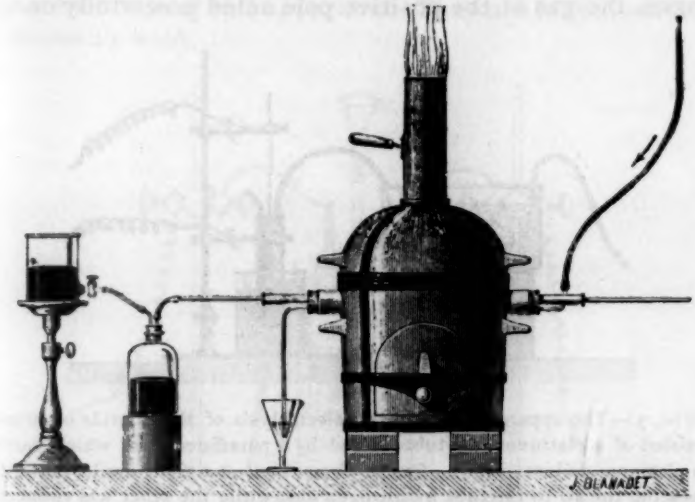


FIG. 2.—Apparatus for studying the action of red-hot platinum on the fluorides of phosphorus and silicon. The metal was used in the form of carefully purified "sponge" and placed in a platinum tube, which passed through a porcelain tube so as to permit enclosing the heated part in an atmosphere of nitrogen gas. The air in the inner tube is then displaced by hydrogen, and this in turn by nitrogen, while the tube is being heated. Finally the gaseous fluoride contained over mercury in the bottle is conducted into the tube as shown in this cut. Although these experiments were variously modified, they only showed that it is useless to attempt isolating fluorine in this way.

at — 23° and can be made to produce temperatures as low as — 50°, by forcing a rapid current of dry air through it.

The first experiments made with this apparatus showed that every trace of moisture must be excluded from the acid, and confirmed also the experience of Faraday and Gore, that the anhydrous acid does not conduct the electric current.

This latter difficulty was easily removed by the addition of acid potassium fluoride, which readily dissolves in the acid and makes it a conductor.

When current was passed through the solution of the potassium salt in the anhydrous acid, bubbles of gas were disengaged at both electrodes. The current continued to flow, and the evolution of gas was quite regular. The gas generated at the negative pole was recognized as pure hydrogen, the gas at the positive pole acted powerfully on the

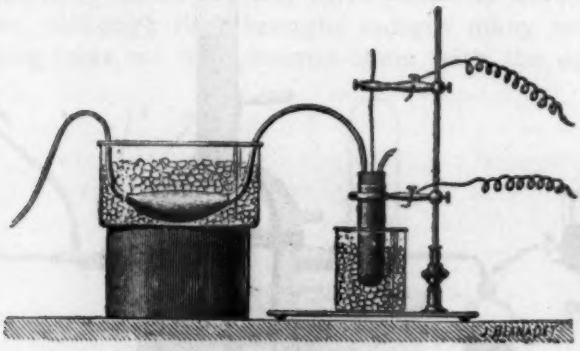


FIG. 3.—The apparatus used in the electrolysis of the fluoride of arsenic consisted of a platinum test-tube, closed by a paraffined cork which carried two platinum delivery tubes. One of these, bent at a right angle, permitted displacing the air in the tube by nitrogen gas, while the other was connected with a platinum receiver, surrounded by cracked ice, in order to condense the fumes of the fluoride. As the cut shows, the tube formed the negative electrode and a wire passing through the stopper served as the anode. The apparatus having been cooled, pure arsenic fluoride was introduced in the tube, the air then displaced by nitrogen and a current from 70 to 90 Bunsen cells passed through the liquid. The separation of arsenic indicated that decomposition occurred, but *no gas* was liberated. Moissan believes that pentafluoride of arsenic was first produced, and this again reacted with the arsenic formed at the same time, the tri-fluoride being regenerated.

platinum electrode, charred the cork, and gave other indications that it might be fluorine.

Before this gas could be collected and studied, however, many obstacles, partly in the construction of the apparatus and partly in the method of working, had to be cleared away.

The apparatus was finally given the form shown in *Fig. 4.* The limbs of the U-shaped tube are closed with care-

fully fitted fluorspar stoppers, through which pass in their axial directions the platinum electrodes.

A lateral delivery tube is attached to each limb of the main tube to permit the escape of the gases. The U-tube is mounted in the lid of the jar containing methyl chloride.

The electric current is derived from a battery of Bunsen elements. It is impossible here to give all the numerous and minute details which it was found necessary to observe in the operation of this apparatus. They are fully described in Moissan's book.

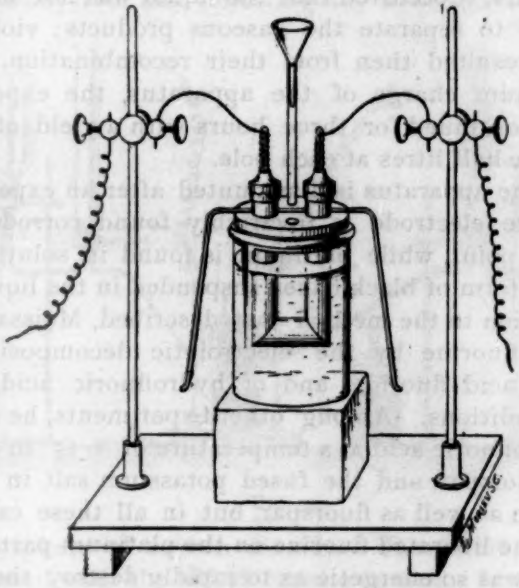


FIG. 4.

The *modus operandi* is briefly this: The hydrofluoric acid, freshly prepared, is introduced in a perfectly anhydrous condition, and about one-half of its weight of absolutely dry acid potassium fluoride is added. The fluorspar stoppers are then inserted and made gas-tight. A temperature of — 23° is steadily maintained during these operations, by the evaporation of the methyl chloride surrounding the tube. The methyl chloride is replenished from time to time.

As soon as the current is made to pass through the liquid, a regular evolution of gas sets in at each pole. The hydrogen given off at the negative pole is readily identified by its burning with a non-luminous flame, giving off water vapor, and by its other well known properties. At the positive pole another gas, apparently colorless, but chemically exceedingly active, is produced.

The first successful experiment of this kind was made by Moissan on June 26, 1886.

When the electrolysis of the liquid was continued for several hours, it occurred that the liquid was not sufficient any longer to separate the gaseous products; violent detonations resulted then from their recombination. With the maximum charge of the apparatus, the experiment could be continued for three hours with a yield of about one and one-half litres at each pole.

When the apparatus is dismounted after an experiment, the positive electrode is invariably found corroded and worn to a point, while platinum is found in solution and also in the form of black flakes suspended in the liquid.

In addition to the method just described, Moissan tried to obtain fluorine by the electrolytic decomposition of potassium acid fluoride, and of hydrofluoric acid, under various conditions. Among other experiments, he electrolyzed hydrofluoric acid at a temperature of $+ 15°$ in a vessel made of fluorspar, and the fused potassium salt in vessels of platinum as well as fluorspar, but in all these cases the action of the liberated fluorine on the platinum parts of the apparatus was so energetic as to rapidly destroy them and render the apparatus useless.

Since fluorine had never been isolated before Moissan succeeded in decomposing hydrofluoric acid by the electric current, it remained for him to furnish proof that the gas liberated at the positive pole really *was* the free element. Its physical and chemical properties, which will be fully described farther on, were found to exactly agree with those which the close analogy of the fluorine compounds with those of chlorine had suggested, but various other hypotheses as to the possible nature of the gas presented

themselves. The gas certainly *was* endowed with wonderful chemical activity; but was it not possible to account for that by the presence of nitric acid, chlorine, ozone, or, perhaps a compound of fluorine with hydrogen richer in fluorine than hydrofluoric acid?

All these assumptions were submitted to the test of experiment and proved to be untenable. The manner in which the absence of hydrogen was demonstrated is of special interest. An apparatus was arranged (*Fig. 5*) which permitted passing the gas produced at the positive pole over red hot iron, and collecting any hydrogen so formed in

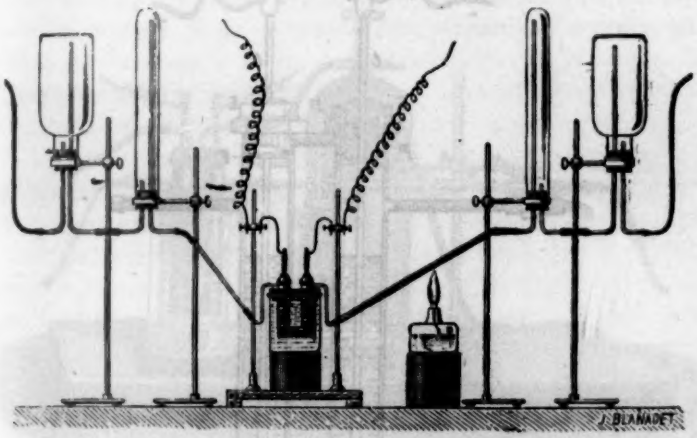


FIG. 5.

an atmosphere of carbon dioxide. The latter could then be removed with the aid of caustic potash. In the several careful experiments made with this apparatus, it was found that the carbon dioxide left only a small bubble of gas on being absorbed by caustic potash, and this residue was air and contained no hydrogen. And it was further ascertained that the increase in weight of the tube containing the iron, corresponded almost exactly to the amount of fluorine equivalent to the hydrogen collected at the negative pole during the experiment. The vapors of hydrofluoric acid were retained in a tube filled with dry potassium fluoride.

For the exact observation of the properties of fluorine, the determination of its physical constants, and the preparation of certain fluorine compounds, it was deemed advisable to procure the gas in larger quantities than the original apparatus had furnished.

Moissan states that hundreds of liters of fluorine were consumed in his researches.

A new apparatus (*Figs. 6 and 7*), of much larger dimensions than the first, was therefore constructed. Its capacity was about 160 cubic centimeters, so that it could receive at

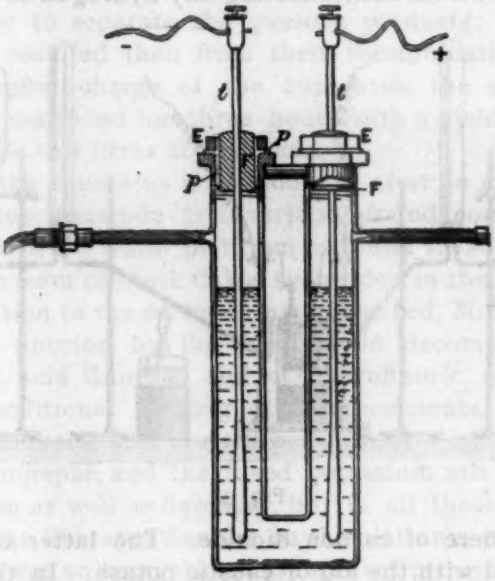


FIG. 6.

least 100 cubic centimeters of the liquid in one charge. The shape of the U-tube, too, was slightly altered, and various minor improvements introduced. The electrodes, for instance, were made of *pure* platinum, instead of the alloy of platinum and iridium, and were very thick at the ends dipping into the liquid.

The glass jar containing the methyl chloride (or other refrigerant) was placed inside another larger jar, containing pieces of calcium chloride to absorb aqueous vapor from the insulating air.

The main improvement, however, consisted in the devices for removing the hydrofluoric acid vapor from the fluorine gas. A small platinum worm condenser was attached to the delivery tube, and the temperature of this condenser was maintained at — 50°, or even lower, by the aid of a suitable refrigerant (liquid air is best adapted, though methyl chloride was used in most of the experiments). The end of the condenser is in turn connected with rather wide platinum tubes filled with pieces of sodium fluoride, a non-hygroscopic salt which retains hydrofluoric acid at the ordinary temperatures. All the joints of the

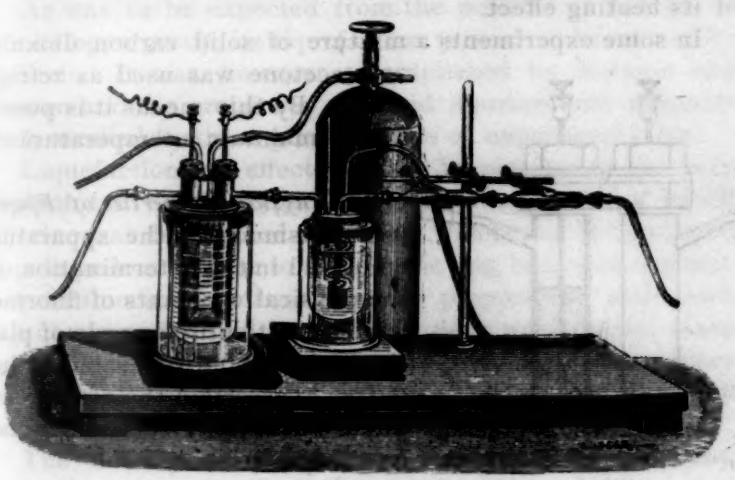


FIG. 7.

apparatus were most carefully rendered gas-tight by means of lead or compressed gold sponge. Lead is only superficially attacked by the fluorine, and gold only at higher temperatures.

The current required was generated by a battery of twenty-six to twenty-eight Bunsen cells arranged in series. This current was made to pass through an ampèremeter and a Bertin commutator.

In one instance 25 ampères and 52 volts were registered before the apparatus was placed in the circuit, and these figures were reduced to 4 ampères and 38 volts when the electrolyte was introduced.

To reduce the cost of the apparatus, and adapt it for commercial purposes (in case practical uses of fluorine should be found) a vessel made of copper (*Fig. 8*), was substituted for the platinum tube, and it was given still greater dimensions. The yield was also augmented by increasing the surface of the electrodes, which, however, had to be made of platinum, as copper was found to dissolve very quickly.

As much as five liters of fluorine per hour were obtained with this apparatus; but, despite energetic cooling, it was not found practicable to increase the current on account of its heating effect.

In some experiments a mixture of solid carbon dioxide and acetone was used as refrigerant. By this means it is possible to maintain a temperature of — 80.°

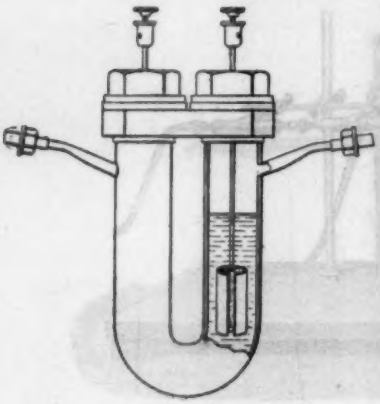


FIG. 8.

(3) *Physical Properties of Fluorine.*—Inasmuch as the apparatus employed in the determination of the physical constants of fluorine were almost entirely made of platinum, it was indispensable at the outset to ascertain the conditions under which this metal is attacked by the gas.

It was found that in the absence of hydrofluoric acid vapor, no appreciable action occurs at 100°; and that energetic combination does not set in below 400°. At about 660° platinum fluoride is very rapidly formed.

In the presence of hydrofluoric acid, fluorine has a corrosive action upon platinum even at 0°.

So thorough has been the investigation of fluorine by Moissan and his collaborators that it may be asserted without exaggeration, that the physical and chemical properties of the new element are as perfectly known as those of any of the other halogen elements.

The odor of fluorine is described as disagreable and

penetrating, recalling that of hypochlorous oxide as well as that of nitrogen peroxide. It is, however, partly masked by the odor of ozone, owing to the presence of moisture. Nevertheless the smell is sufficiently characteristic to permit the detection of even traces of free fluorine in fairly dry air. The gas is dangerous to inhale even in very small quantities, as it produces violent bronchial irritation and mucous anæsthesia lasting for several weeks.

The color of the gas is greenish-yellow, but much paler than that of chlorine. It is distinctly seen on looking through a stratum of one meter in thickness.

As was to be expected from the position of fluorine in the halogen group, its liquefaction proved to be extremely difficult. It was, however, accomplished by Moissan and Dewar, and the properties of liquid fluorine were exhaustively studied by these great masters of experimentation.

Liquefaction was effected a few degrees below the boiling point of liquid oxygen, and the boiling point of liquid fluorine was determined at — 187°. The color of this liquid is pale yellow, similar to that of the gas, but more distinct. Liquid fluorine is miscible in all proportions with both liquid air and liquid oxygen. It does not congeal when cooled to — 210°. Its density is 1·14, and its capillary constant is smaller than that of water, alcohol or liquid oxygen.

The density of fluorine gas was found to be 1·265, instead of the theoretical value of 1·316.

Spectroscopically the gas is characterized by thirteen lines in the red, having wave lengths which range between 744 and 623. The most brilliant of these lines are 677, 640·5, 634, and 623. In layers of one meter in thickness the gas presents no absorption spectrum.

(4) *The Chemical Properties of Fluorine* are more powerful than those of all the other known elements.

Thus it unites energetically with hydrogen gas, even in the dark and at temperatures as low as — 210°.

It inflames both bromine and iodine, but shows no tendency to combine with chlorine.

Sulphur, selenium and tellurium take fire spontaneously

in the gas. Sulphur yields a mixture of gaseous fluorides, while selenium and tellurium are converted into solid compounds.

Oxygen, nitrogen and argon do not appear to enter into combination with it under any conditions.

Phosphorus reacts very energetically. The main product is the pentafluoride, PF_5, a gas. In addition to this, Moissan has prepared two other gaseous fluorine compounds of phosphorus, the trifluoride, PF_3, and the oxyfluoride, PF_3O. All three substances were made the subjects of extended investigations by him.

Arsenic and antimony combine with fluorine at the ordinary temperatures forming the corresponding fluorides. In both cases the union is attended with incandescence.

Crystallized silicon, lamp-black and amorphous boron all take fire when projected into fluorine gas, and are converted with extreme energy into fluorides.

By this means a mixture of fluorides of carbon was obtained, of which the tetrafluoride, CF_4, has been specially studied. It was also prepared in several other ways. It is a gas having a density of 3·09, and is liquefied under atmospheric pressure at $-15°$. Insoluble in water, it dissolves readily in alcohol and ether. It attacks glass, especially at higher temperatures, and is readily decomposed by heating in contact with metallic sodium, and also by an alcoholic solution of caustic potash.

The action of fluorine on the metallic elements is less energetic than that on most of the non-metals, owing to the formation of solid fluorides which form protecting coats upon their surfaces.

The metals of the alkalies and alkaline earths inflame spontaneously in fluorine.

Microscopic crystals of fluorspar were obtained artificially when pure calcium metal was burned in fluorine.

Lead is but slowly transformed into the fluoride, but iron reduced by hydrogen becomes incandescent in contact with the gas.

Magnesium, aluminium, nickel and silver, upon being gently heated in fluorine, all take fire and burn in it with great brilliancy.

When manganese is exposed to a current of the gas, it is converted into a beautiful crystallized compound, having a violet color, manganic fluoride, $Mn F_3$. At a low red heat the latter abandons fluorine, and manganous fluoride, $Mn F_2$, remains.

Gold and platinum are not attacked by fluorine below a red heat, and the fluorides which result at this temperature are again resolved into their constituents at still higher temperatures. The formula of the platinum fluoride so obtained is $Pt F_4$.

Among the most remarkable chemical reactions of free fluorine is the decomposition of water at ordinary temperatures (*Fig. 9*). The products are hydrofluoric acid and ozone.

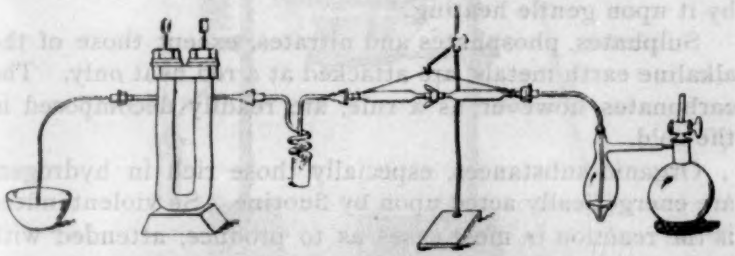


FIG. 9.—Apparatus for demonstrating the action of a large volume of fluorine upon a small quantity of water. Fluorine produced in the large copper generator (*Fig. 8*) is conducted into water contained in a small glass bulb, cooled to 0°. The gas is thence passed into a balloon, such as are used in determining the density of gases; it is a mixture of oxygen and ozone, in which the proportion of the latter may be determined by means of potassium iodide.

When the fluorine is present in considerable excess, the ozone produced is sufficiently concentrated to show its beautiful blue color. With a slight excess of water, and at a temperature of 0°, oxygen gas containing as much as 19 per cent. of ozone and entirely free from oxides of nitrogen may be obtained.

Some compounds, such as hydrogen sulphide, sulphur dioxide, hydrochloric, hydrobromic and hydriodic acids take fire in contact with fluorine.

Phosphorus trifluoride combines with it to form the pentafluoride.

The oxides of carbon do not appear to react with fluorine, but carbon disulphide as well as cyanogen are inflamed by it.

Both the metallic and non-metallic chlorides, bromides, iodides and cyanides are decomposed in the cold by fluorine gas.

The latter reacts also on a large number of metallic oxides, either in the cold, with the alkaline earths for example, or at a low red heat, as is the case with the oxides of iron, nickel, zinc, and lead.

The same is true of the sulphides.

The phosphides and arsenides are for the most part attacked at ordinary temperatures.

The carbides of lithium and the alkaline earth metals are rendered incandescent in contact with fluorine, while those of aluminum, zirconium and uranium are decomposed by it upon gentle heating.

Sulphates, phosphates and nitrates, except those of the alkaline earth metals, are attacked at a red heat only. The carbonates, however, as a rule, are readily decomposed in the cold.

Organic substances, especially those rich in hydrogen, are energetically acted upon by fluorine. So violent indeed is the reaction in most cases as to produce, attended with evolution of light and heat, the total destruction of the compound, the products being hydrofluoric acid and fluorides of carbon.

The hydrocarbons and their derivatives take fire in fluorine; the alcohols and ethers are mostly acted on in the same way.

Organic acids react less readily, especially those of complex molecular structure.

Amines and many of the alkaloids burn rapidly in fluorine, yielding volatile products.

All these reactions, however, are much too violent to lend themselves to the study of organic fluorine compounds. It was in other ways that substances suitable for this purpose were procured.

By taking advantage of the double decompositions between the fluorides of silver and zinc, on the one hand, and the iodides of various hydrocarbon radicals, on the other, Moissan succeeded (*Fig. 10*), in preparing the fluorides

of ethyl, methyl and isobutyl, and M. Meslans continuing these researches added fluoroform, acetyl fluoride, the fluohydrins of glycerol, as well as propyl, isopropyl, and allyl to the list of organic fluorine compounds.

Most of the organic fluorine compounds previously studied, belonged to the benzene series, and only few of the aliphatic derivatives mentioned had been prepared. Even these had been imperfectly studied and characterized.

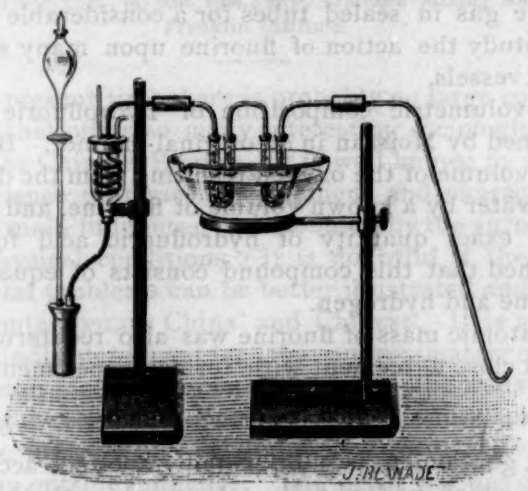


FIG. 10.—Apparatus used for preparing ethyl fluoride. This consists of a brass tube fitted with a double-perforated cork, carrying a separatory funnel and a leaden worm condenser tube. The latter is cooled to −23° by the aid of methyl chloride, and connected with two U-shaped glass tubes which contain silver fluoride, and are immersed in water of 40°. Fluoride of silver is placed in the brass vessel and ethyl iodide allowed to fall on it drop by drop from the funnel. Ethyl fluoride escapes as a gas, while fluoidide and presently iodide of silver are produced. The vapors of ethyl iodide which accompany the gas are mostly condensed in the worm and the remaining traces are removed by the silver fluoride in the U-tubes.

The results of the investigations by Moissan and Meslans on the fluorine substitution products may be summed up in the statement that they are the perfect analogues of the corresponding compounds of the other halogen elements, and that their study confirmed the position of fluorine at the head of the halogen group.

Experiments with fluorine conducted at very low tem-

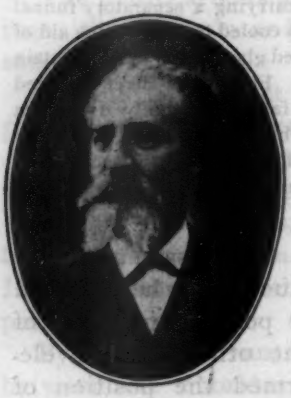
peratures showed that, while its chemical energy was greatly reduced, it was still capable of reacting at temperatures as low as — 210° with hydrogen and with certain hydrocarbons, such as oil of turpentine.

The action of hydrofluoric acid and of fluorine on glass was also carefully investigated. It was found that the glass was attacked by the former at the ordinary temperature, but that fluorine acted so slowly that it was possible to preserve the gas in sealed tubes for a considerable time, and also to study the action of fluorine upon many substances in glass vessels.

The volumetric composition of hydrofluoric acid was determined by Moissan in an original manner. By measuring the volume of the oxygen resulting from the decomposition of water by a known volume of fluorine, and ascertaining the exact quantity of hydrofluoric acid formed, he established that this compound consists of equal volumes of fluorine and hydrogen.

The atomic mass of fluorine was also redetermined, and found in close agreement with former experimenters, to be 19·05.

Such, gentlemen, is a brief and imperfect account of a research which undoubtedly takes rank with the greatest masterpieces recorded in the annals of inorganic chemistry. This research was not prompted by a current theory or fad, but attacked an old problem, the solution of which required a rare combination of sagacity, perseverance, resourcefulness and, last but not least—heroism, all of which Henri Moissan has shown himself to be possessed of in an extraordinary degree. In isolating fluorine and studying its properties and its compounds, he has verified the brilliant prognostication of Ampère and Davy, and fixed the position of the element in the natural system.



HENRI MOISSAN.

Mining and Metallurgical Section.

Stated Meeting, held March 13, 1901.

SOME EFFECTS OF DEFORESTATION IN CHINA.

By F. Lynwood Garrison,

Asso. M. Am. Soc. C.E., M. Am. Inst., M.E. Professor Mining Engineering, Franklin Institute.

At the present time there is probably no large country in the world that offers so many interesting sociological problems as the Chinese Empire. It is well known to students of this science that race development and characteristics are in the main influenced and moulded by the surrounding natural physical conditions. It is doubtful if these great fundamental problems can be better illustrated and studied than in contemporary China and Chinese. It is a curious and profoundly significant fact, that approximately one-third of the human race have gone on for many hundreds of years developing a civilization peculiar to themselves, and, if we except the introduction of Buddhism, very little if at all affected by outside influence. The great nations of antiquity have arisen, flourished and crumbled into dust, whilst the Chinese have gone on the even tenor of their way, that was much the same a thousand years ago as it is to-day.

Bounded on the east, southeast and south by the sea, on the west by the jungles of Burma, Siam and the tremendous mountains of Thibet, and on the north by the deserts of Mongolia, this great country is uniquely hedged in by natural barriers not to be overcome until steam navigation made the sea an easy and safe highway for mankind. Unlike Japan, China has resisted and shrunk from the touch of modern western civilization with its wheels, cranks and hissing steam. Culminating in the present crisis, the Chinese can resist no longer. The fiat has gone forth, take your place with the other nations of the earth, lest your national existence be extinguished forever!

We have now reached a time when it will be possible to study this interesting and peculiar people, to see in what manner they have used and abused their birthright. How have they lived in and cared for this beautiful and fruitful country; have they utilized its resources in a proper manner? As yet we possess relatively very little knowledge of the interior of this huge empire, but judging from the observations so far recorded, we would say the Chinese have abused their natural resources without check or stint. We need not, for our present purpose, inquire into causes of such effects, further than is absolutely necessary in order to determine how to avoid making similar mistakes in the care and preservation of our own great and splendid fatherland.

The protestations from well informed organizations and individuals against the destruction of our forests in the United States have been so persistent and well sustained that general public interest has been now aroused to some sense of responsibility.

While it is obvious to every one that our timber resources are rapidly melting away, very few realize the dangers of this deforestation, or its effects upon the productive capacity of the country as our population becomes rapidly denser.

Droughts we have had, but famines never. Will famine be the concomitant of drought when our population numbers 400,000,000? is the natural and irresistible reflection in this connection.

If any doubts that drought, flood and famine follow deforestation as surely as night succeeds day, let him visit China and carefully study the writings of the few competent observers who have lived in and travelled through that little known country.

It is safe to say that drought, flood and famine are of annual occurrence in one or another portion of the Middle Kingdom, and that the famines are apt to be severe owing to the lack of efficient transportation from more favored sections of the Empire. It must not be assumed, however, that even a thoroughly good system of railways throughout China

would prevent famine, though undoubtedly it would check absolute starvation.

Russia, which is well provided with railways, seldom has a year without famine. Grinding poverty, filth and superstition are the common lot of the Chinese peasant and the Russian muzhik, and if there is any choice the Chinaman is probably the better off of the two. Similar causes have produced similar effects in both countries, deforestation has already ruined much of China and is beginning to spoil some sections of European Russia. There is a general tradition amongst the natives throughout the whole of the Middle Kingdom that the mountains and hillsides were once covered with forests and that the rains have decreased in frequency and increased in violence from generation to generation. In China as in some other countries the floods were formerly regular during successive years, whereas at later periods they have grown more irregular and violent. In mountainous regions torrential rains do not soak into the bare uncovered earth, the rapid run-off tears up the soil, fills the water courses and lakes with gravel and sand. Standing on the mountain tops of Eastern Shantung last summer, it was not difficult for the writer to picture in his mind those bare brown hills covered with primeval forests, the dry rocky gulleys filled with babbling brooks, and the deep valleys studded with beautiful lakes and streams now filled and choked with sand and gravel. The once deep-bayed indentations of this fine sea-girt province are deep no longer, but are now so silted that a good anchorage for deep-draft ships can only be obtained even in the best of the harbors, like Wei-hai-wei and Kiao-chau by constant dredging. The celebrated geographer and geologist Baron von Richthofen, in speaking of Shansi province, remarks "that the traveller at every step has occasion to contrast the present poverty and inertness of the inhabitants, with the signs of a previously better condition. The large cities, even villages, the temples, the remains of magnificent public structures, as well as the history of China, give evidence that the northern provinces have been in a more prosperous state." The cause, aside from politi-

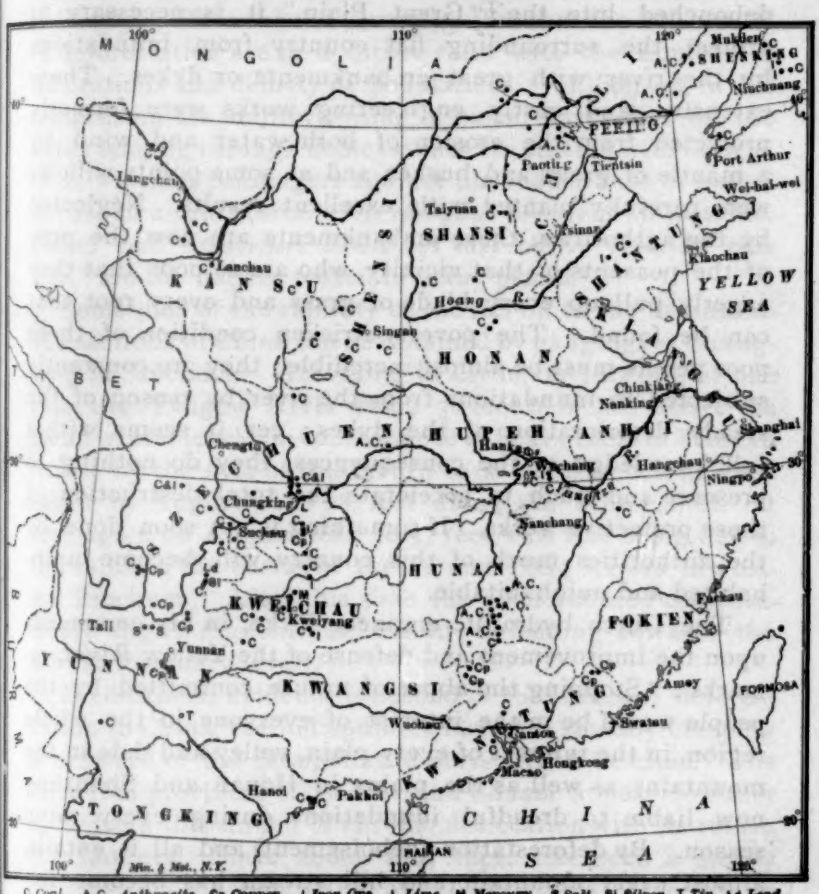
cal, that led to these conditions Richthofen believes is the deterioration of the climate, which is the probable consequence of the extermination of the forests. Throughout the whole country, from Hankow to Peking the mountain and hill sides are destitute of trees and shrubs and offer a most desolate aspect. The exceptions are the groves of trees at the villages and temples and parts of the Fu-niu-shan mountains where many hillsides are planted with oak trees for feeding wild silkworms. Richthofen thinks there are no positive proofs that these conditions had formerly been otherwise, but it is exceedingly probable and the people everywhere assert that their mountains were covered with trees in old times. He further states that besides this injurious effect of the destruction of the forests upon the climate in general, there is an immense amount of deterioration incessantly going on, which would not take place if the hills were wooded. The heavy rains wash off the soil from the rocks, and the water, instead of penetrating into the earth, and being stored up for feeding springs, runs off the hillsides and descends in torrents through gulches which were before perfectly dry. In the valleys, the rivers in overflowing their banks spread much fine sand or silt over the surface of the fertile alluvial soil, thus often rendering extensive regions unfit for agriculture. Instances of this kind are, according to Richthofen, numerous in Shansi, on the borders of the great plain. If it were not for the *löss* formation, he declares that northern China would already be a desert with some fertile valleys enclosed. Even this beneficial formation, which is the principal seat of agriculture and, more than other kinds of soil, capable of storing up moisture, is undergoing a rapid destruction.*

Archibald J. Little,† in writing of Szechuen province, remarks that at the present time in China wherever there is a stream that will float a log, there are no logs to float, and he might have added that in places where timber could not be in any way transported, it is converted into charcoal.

* "Richthofen Letters." Shanghai, 1870–1872, p. 37.

† "Mount Omi and Beyond." London, 1901, p. 257.

Little says the Chinese have a regular locust-like propensity to destroy every green thing wherever they penetrate; for when the trees are gone, comes the turn of the scrubs and bushes, then the grass and at last the roots, until finally the rain washes down the accumulated soil of ages and



C Coal A.C. *Anthracite* Cp Copper I *Iron Ore* L *Lime* M *Mercury* S *Salt* Si *Silver* T *Tin* Ld *Lead*

[*By courtesy of "Mining and Metallurgy," New York.*]

barren rocks remain. While this statement may be rather extreme, there is reason to believe the rainfall has considerably diminished in many portions, and is much more irregular and uncertain. All observers agree that the rivers have shrunken in volume and droughts occur where they

had been quite unknown. According to Little, in northwestern Szechuen, in what is known as the "red basin" situated at the foot of the mountains, there have now been successive seasons of drought.*

On the Yellow River below Kai-fung-fu, after it has debouched into the "Great Plain," it is necessary to protect the surrounding flat country from inundations by the river with great embankments or dykes. These extensive and costly engineering works were formerly protected from the erosion of both water and wind, by a mantle of grass and bushes and at some points willows were carefully planted with excellent results. Neglected by the authorities, these embankments are now the prey of the peasants of that vicinity, who are so poor that they eagerly pull up every blade of grass and every root that can be found. The poverty-stricken condition of these poor people must be almost incredible; they are constantly subjected to inundations from the river by reason of the steady deterioration of the dykes; yet, it seems with a full knowledge of the consequences, they do nothing to preserve and much to accelerate the total destruction of these protective works. If something is not soon done by the authorities much of this country will become uninhabited and uninhabitable.

The Dutch hydraulic engineer Ryke, in his comments upon the improvement and defense of the Yellow River, remarks: "Stopping the abuse of nature committed by the people would be in the interest of everyone in the whole region, in the interest of every plain, valley and dale in the mountains, as well as the plains in Honan and Shantung now liable to dreadful inundations during every rainy season. By deforestation (deboisement) and all it entails, almost every mountain and hill stream has become torrential, and this means that the rainwater leaps downward in waves as soon as it falls; it means further, as a matter of course, the misery of a water famine in dry seasons." Ryke affirms that upon several occasions when it was neces-

* *Ibid.*, p. 257.

sary to examine a mountainous section of country for the sake of a stream, or for plains liable to inundation, he had only to look on the map of the district to know beforehand where to find the worst cases and they were invariably where the greatest number of villages and hamlets were indicated. He means of course by this that the evil results of deforestation are in a direct ratio with the number of habitations and density of population. Williamson, in his remarks on his journey through Shansi, states that on the roads leading through defiles stones are erected with inscriptions warning passengers against the sudden rush of waters in case of a rain storm. "*At this place beware of the mountain water*," and "*travellers should not take shelter from the rain here*," are the notices posted in many places.*

Some idea of the rapidity of the run-off in the mountainous sections of China can be obtained by gaugings at Chungking in Szechuen. According to Little, on July 6th, of one year, the Yangtse River stood 38 feet 6 inches above the mean winter level; in consequence of heavy rains in Yunnan it rose by the 13th of this month to 96 feet 8 inches, and fell again by August 3d to 28 feet above the winter level. It rose again on August 16th to 57 feet, this rise being due to the rains in the basins of the Ta and Tung Rivers in western Szechuen. After this date the river suffered comparatively slight fluctuations, steadily subsiding towards the lowest February level†.

If additional evidence is needed of the effects of deforestation in China, the indisputable fact of a steadily creeping southward of the Mongolian deserts might be cited. The once rich provinces of Shensi and Shansi appear to suffer most from this inroad of chronic desiccation with its resulting famines. Since about 1845 there has been a steady decrease in the population of the provinces bordering on the deserts, namely Shansi, Shensi, Kan-su and Chili. No doubt this has been due in some measure to other causes,

* Rev. A. Williamson, Journal North China Branch, Royal Asiatic Society. New Series.

† "Mount Omi and Beyond." A. J. Little. London, 1901. Pp. 119.

such as the Taiping rebellion and other political disorders. But the probabilities are that cultivatable area in these provinces is steadily shrinking, and has in a great degree been caused by the destruction of the protecting forests. In this connection we have some grounds for an interesting speculation as to whether or not certain well developed facts warrant the belief that much of the territory now desert was a habitable and fertile country in historic times. It is not possible to discuss the subject in this paper, save to say that unmistakable evidences of a comparatively high civilization have recently been discovered in the midst of what are now and apparently have long been hopelessly desert areas. It may, perhaps, be going too far to assume that the climatic changes which have brought about such results have been entirely due to deforestation. The probabilities are that other forces have been at work, but until the problem has been intelligently studied, it is hopeless to attempt its solution. Careful and scientific observations of rainfall, flow of streams, etc., have yet to be made in China. It is only at Shanghai and Hong-Kong that metereological data covering any considerable period of years have been accumulated.

Marco Polo speaks of the Yangtse River as being thickly wooded in places where a tree is not now to be seen for miles. According to the naturalist Pratt, there are now no trees worth felling in the Yangtse valley within any distance of a stream that might be used for logging.*

Another naturalist, Père Amand David, cannot believe this reckless destruction of the forests which characterizes the march of Chinese civilization to be altogether due to the need of firewood. He attributes it rather to the fear of wild beasts and a desire to destroy any cover for them. In Szechuen and in a number of other provinces of the Yangtse drainage area, the natives mine and use considerable quantities of coal. Where this is abundant and cheap, it is not likely they are under much stress for fuel, as is the case in the "Great Plain," and along the banks of the Yellow River

* "The Snows of Thibet and through China." A. E. Pratt.

below Kai fung-fu. The theory of Père David's may, therefore, be correct, for the Chinese, as a rule, certainly have great fear of the tigers that are usually found in the wilder parts of China.

It is rather remarkable that so practical a people as the Chinese should not have long ago recognized the many advantages of forest culture, that is, in the sense of raising trees as an agricultural product. It seems, however, insome localities, nota-bly in Hunan province, attempts have been made at replanting the hillsides with ordinary timber trees. But this is quite exceptional, for, as a rule, only those trees are considered worth growing that yield a comparatively quick return or harvest. The yield of the varnish tree (Rus vernicifera) the camphor (Cinnamomum camphora), mulberry (Morusalba), mountain oak (Quercus esculus), and the bamboo (Bambusa) form alarge portion of the natural products of China, the mulberry being, of course, used in silk culture as is likewise the mountain oak.

The usual Chinese system of cultivation by means of terraced fields rising one above the other up the side of a hill or even mountain, does certainly tend to check erosion. These systems of terraced paddy fields are generally placed where possible athwart the course of small streams.

The French use barriers of a similar kind especially constructed to check erosion, and enable the soil to accumulate on steep hillsides in sufficient quantity to give foothold and sustenance to trees. In China one often sees, especially in those provinces ravished by the Taiping rebellion, abandoned fields of this kind covered with small trees or bushes, showing thus that the hillsides could be easily planted with trees were it possible to give up their use for agriculture.

It has been estimated under normal conditions in well forested areas, that about one-sixth to one-third of the whole rainfall flows off into the sea, the five-sixths or two-thirds sinking into the earth, where it is conserved to supply springs and wells. It follows, therefore, when the protecting cover is removed, there is little less to hold the water from immediately running off, consequently less and less soaks into the earth and the level of the ground water

steadily decreases, drying up the springs, wells and ooze that is very beneficial to vegetation. This statement has been so well substantiated by careful observations in Europe and America it scarcely needs reiteration. The existence of forests probably increases the amount of rainfall, because fogs and clouds, saturated with aqueous vapor, which sweep over it, are condensed by contact with the leaves and branches. Furthermore, the temperature of the air in forests is considerably lower in daytime and higher at night than that over cleared areas; this condition presumes a local circulation of the air, which has the effect of driving fogs or clouds into its bosom and a consequent deposition of the contained moisture. But probably the most potent effect of trees in conserving rainfall is from the fact that much of the rain is temporarily held by the leaves and falls to the ground slowly, giving it a longer time to soak into the ground. Forests also render this process more easy by the roots, which spread out over a large area, forming channels through which the rainfall filters and sinks deeper and deeper into the earth. It has been estimated by experiment that the aqueous vapor which forms over cleared fields is at least four or five times as great as that over a wooded tract, and consequently that the water which has oozed into the soil of the latter does not vaporize so easily, but is retained and serves to feed the surface springs and rivers.

It seems most extraordinary that a practical, intelligent and observing people like the Chinese should have failed to recognize some of these facts, and that seeing their country becoming steadily more and more arid and difficult to cultivate, some effort should not be made to mitigate or check the evil.

At the present time the normal annual rainfall at Peking is 16 inches and as the coast is approached it increases steadily. As far as I know no records have been kept in eastern Shantung; hence any estimate of the annual precipitation at say Chee-fu and Wei-hai-wei is a mere conjecture. Starting with 16 inches at Peking as a basis and studying carefully the conditions of the country between there and Chee-fu we may assume the rainfall in eastern Shantung

at 40 inches. According to Chinese historical records the climate of northern China has undoubtedly moderated considerably from what it was some centuries ago. This has been correctly attributed to the effects of deforestation. While the total annual precipitation has probably not greatly decreased, it is unevenly distributed, drought follows flood, and there are distinctive wet and dry seasons that are unusual in a temperate climate in much the same latitude as Philadelphia and surrounded on three sides by the sea.

At Hong-kong, Macao and Canton the annual rainfall is great, averaging 86 inches, and in 1891 was exceptionally high at 117 inches. In northern China the rainy season lasts about two months, July and August approximately. While the ill effects of deforestation in many portions of China are sufficiently obvious, it is not so easy to draw conclusions as to resulting influences upon the character of the people. Poor and unhappy they certainly are, overpopulation has stretched the food-supply about to its elastic limit. A failure of crops in any section entails starvation on the part of most of the inhabitants in that district, for transportation is usually so crude and costly, that supplies from other parts of the Empire cannot be delivered at a cost that will be within the ability of nine-tenths of the people to pay. Some sections are of course more fertile and favored than others, but it is evident in the best of them such dense populations cannot long continue to live by the soil alone. Unless therefore the Chinese encourage and extend their manufacturing industries and particularly develop their marvelous mineral resources, they cannot prosper, but will revert to savagery. The whole Chinese question, both political and religious, therefore, resolves itself into a purely industrial one. At the present time the Chinese nation is undoubtedly decadent, but the people as a whole certainly cannot be so considered. Political corruption, an absurd conservatism and self-conceit are the bane of the country. Yet political corruption is not unknown in other countries, and we regret to think even in those that supply the Chinese with most of their foreign moral and religious instructors. In a word, the Chinese house is worn out, it is filthy and rotten; place

its inhabitants in a clean new one and they will astonish the world with their prosperity and progress, moral, religious and industrial.

METALLURGY OF ALUMINUM.

The following item, gleaned from the "Digest" department of the *Electrical World*, may be classed as "highly important, if true," viz. :

Metallurgical processes which involve the use of calcium carbide as the reducing agent, possess an especial interest due to the fact that they are, in an indirect manner, electro-chemical, for the energy used for the reduction is as truly electrical as though the effect was produced directly by electrolysis instead of indirectly through the medium of the carbide furnace. Hence a discussion of such processes always involves the question of relative efficiencies as between fused bath electrolysis and electric furnace reduction—a question which generally solves in favor of the furnace. This question is raised but not answered by a patent recently issued (May 28) to Mr. Henry Spencer Blackmore, of Mount Vernon, N. Y., for the reduction of aluminum compounds by the reaction therewith of a carbide. Mr. Blackmore finds that aluminum oxide is reducible by aluminum carbide with liberation of the metal of both reacting bodies and in accordance with the equation $Al_2O_3 + Al_4C_3 = 6Al + 3CO$, the reaction being strictly analogous to that employed by M. Moissan some years ago for the preparation of metallic chromium. If, however, the oxide and carbide of aluminum be employed in the solid state it is found that the aluminum is either volatilized or so distributed through the residual charge as to render its collection impracticable, and accordingly it is proposed to suspend or dissolve the oxide and carbide in a molten bath, which remains inert with respect thereto, and which so reduces the temperature of the reaction and so alters the character of the medium as to permit the liquid metal to be tapped off. Two procedures are described : In the first, a mixture of cryolite and lithium fluoride is fused, and the oxide and carbide of aluminum are alternately added, the reaction occurring readily, it is said, and the aluminum separating freely. In the second, oxide of aluminum is added to the bath and calcium carbide then introduced, the effect being to produce aluminum carbide within the bath by reaction between the cryolite and the carbide of calcium, this aluminum carbide then reacting with the oxide present to yield the metal. The calcium fluoride formed interferes to no marked degree with the operation, and in the early stages serves to promote the fluidity of the metal. Eventually, however, the bath must be regenerated or renewed. Mr. Blackmore is authority for the statement that he has succeeded in producing aluminum by reduction by calcium carbide, on an experimental scale, at an expense not exceeding 7 cents per pound. W.

Section of Photography and Microscopy.

Stated Meeting, held May 2, 1901.

THE CHAPMAN JONES PHOTOGRAPHIC PLATE TESTER.

BY FREDERIC E. IVES,
Member of the Institute.

This device, which was demonstrated by Mr. Frederic E. Ives, at the stated meeting of the Institute, in May, is thus described by the inventor:

The object of this apparatus is to provide an easy and rapid means of ascertaining, within a sufficient degree of accuracy to be of practical value, the relative working characteristics of photographic plates and films. It consists essentially of a screen plate 4¼ by 3¼ inches, containing:

(*A*) A series of twenty-five tints of graduated densities.

(*B*) A series of colored squares and a strip of neutral gray, all five being of approximately equal luminosity.

(*C*) A series of four squares of special colors, each color passing light from a definite portion of the spectrum, and

(*D*) A square of a line design over which is superposed a half-tone negative.

In order to use the instrument, a quarter-plate of the brand to be tested is simply exposed behind the screen for a few seconds, developed, fixed and washed.

Simple examination of this one plate will show sensitiveness, or speed, sensitiveness to color, range of gradation, comparative size of grain of plate, possible range of exposure, amount of halation, the most suitable light for development. By further exposures, the instrument can be used for testing and adjusting developers, testing media for dark-room illumination, examination of light filters, testing plate backings, etc., etc.

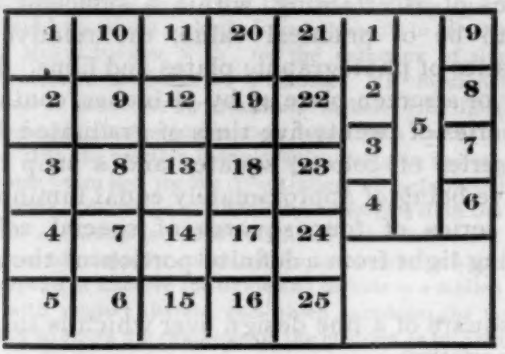
Although nearly all makers give some indication on their packages with regard to speed and other characteristics of

their plates, the conditions under which they make their tests are not uniform.

One very great advantage of the little instrument is that it enables the actual user of plates to ascertain quickly and with a minimum of trouble, the *comparative* usefulness of the various brands on the market for his *own special purpose*. The record obtained is a permanent one, always ready for reference.

THE APPARATUS.

The Screen Plate.—The essential part of the apparatus is the screen plate shown in *Fig. 1*. The screen, which is of the same size as the ordinary quarter-plate, 4¼ by 3¼ inches, contains:



(*A*) A series of twenty-five tints of graduated densities, each numbered for identification, but in such a way that the larger part of each tint is available for comparison with other tints or for measurement.

(*B*) A series of four small colored squares and a strip of gray, Nos. 1 to 5, all five being of approximately the same luminosity and constituting what is known as the Abney Color Sensitometer in its simplest form.

(*C*) A set of four squares of special pure colors each of which represents a definite portion of the spectrum, the division of the spectrum into parts being made in such a manner that the information given is just that which is most useful.

The square 6 transmits all the light to which ordinary plates are usefully sensitive (ultra-violet, violet and blue, as far as the Fraunhofer line *E* or *b*).

Square No. 7 transmits the green to which isochromatic plates are sensitive, in addition to the sensitiveness of ordinary plates (*E* or *b* to *D*). The first red (No. 8), transmits only the red to which some orthochromatic plates are sensitive, when the extreme red is reserved as a useful light for the dark room, namely *D* to *C*, and the last red patch (No. 9), transmits only the red beyond *C*, these four patches therefore divide the spectrum into four definite portions, the remaining portion of the area of the instrument is occupied by a line negative over which is superposed a half-tone negative from a plaster relief. This half-tone negative being about the density of an ordinary (*thin*) negative gives an indication, the value of which every photographer will at once recognize.

It is only necessary to expose a plate for a few seconds behind this screen and develop it, when the resulting negative shows at a glance all the information the photographer usually desires, and no scientific knowledge is necessary to interpret the result. By further examination of this plate, results of a quantitative character can be obtained. Several tests are made at one time, but the different parts of the apparatus do not interfere with each other or necessitate compromises; indeed, they add to each other's value.

Mr. Ives said he believed that all of the separate tests included in this device had been used before, but that their combination in a single handy device was due to Mr. Chapman Jones, and that Mr. Jones by his suggestion, and Mr. Sanger Shepherd, by the very efficient manner in which he had provided for quality and uniformity in their manufacture, had conferred a boon upon the photographic fraternity. He thought that every photographer should know his tools and there could be very little excuse for anyone to remain in ignorance of the capabilities and limitations of his photographic plates when such a cheap and handy device could be made to tell practically all the story.

EFFECT OF HEAT ON BABBITT METAL.

Almost any solid metal for lining bearings is called by the name "babbitt metal," while in fact few of the soft linings used have any claim whatever to that title, says *Modern Machinery*. The genuine alloy which was compounded by John Babbitt, and which bears his name, is composed of eight parts regulus of antimony (regulus means the pure, refined metal) four parts copper and ninety-six parts of tin.

Ordinary soft lining, so-called babbitt metal, frequently is made up of four parts lead and one part antimony. Old type metal is also used for lining, and consists of two parts lead, one part tin, and one part antimony. Britannia metal (pewter) is much used for lining, and this consists of nine parts tin and one part antimony.

It will be noted that all the alloys above described are partly of antimony, and also contain either lead or tin, both easily oxidized metals. But antimony is even more easily oxidized, and will burn in the open air if too highly heated, much like zinc. Thus, when either of the alloys described above is frequently heated, the different metals become oxidized, but burn out in different ratios to each other, thereby changing the nature of the alloy to a certain extent each time it is heated.

Genuine babbitt will probably change its form more by reheating than the alloys of antimony and lead, but the latter are reduced the most in quantity. The reason, therefore, is that the copper and tin oxidize more slowly than the antimony, which quickly burns out, leaving the babbitt much softer than it was before getting rid of some of its antimony. Lead oxidizes much more freely than either copper or tin, therefore the alloy retains more nearly its original composition when a quantity is burned off or oxidized; still the antimony burns out faster than the lead, reducing the hardness of the alloy, but not to the extent it does when mixed with tin and copper. Under proper conditions, any kind of babbitt metal may be melted, and even kept indefinitely in a molten condition without oxidation, or, in every-day language, without the forming of dross on the surface of the molten metal. To secure this result, protect the metal from the atmosphere. A layer of dirt on top of the molten metal will do it; even a layer of oxide or dross is a good preventive; therefore do not skim off the layer of oxide as fast as it forms, but let it stay on top of the hot metal.

A very good way is to cover the metal in the ladle or melting pot with pulverized charcoal. Carbon largely retards the process of oxidation, and if some salt and soda (common washing and cooking soda) be added to the coarsely-powdered charcoal, the oxide will be reduced—that is, the dross will be smelted back into the metal again.

Another preventive of oxidation of babbitt metal lies in not heating the metal too hot. For all except very small bearings, where the layer of metal must run very thin, there is no need of heating the metal very hot. Just hot enough to barely char a dry pine stick, is a good rule to follow when heating babbitt metal. But whittle the stick every time the metal is tested, so that a fresh wooden surface is exposed thereto.

Section of Photography and Microscopy.

Stated Meeting, held May 29, 1901.

A NOVEL FORM OF LANTERN POLARISCOPE.

By Frederic E. Ives,
Member of the Institute.

Owing to the high cost of large Nicol prisms, lantern polariscopes with stages large enough to take the regular mica and selenite designs, chilled glasses, etc., are now almost always made with bundles of glass as polarizers, and in order to avoid turning the lantern aside, as was necessary

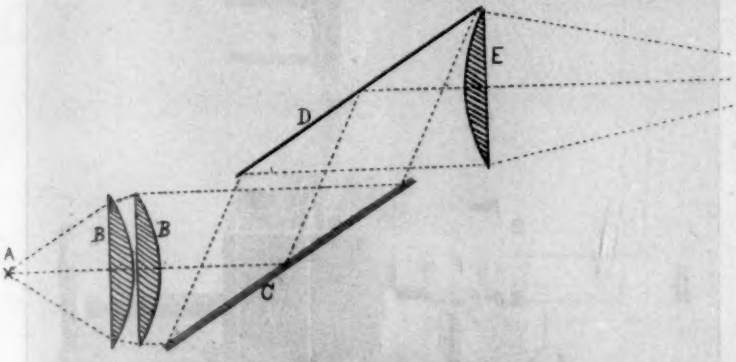


Fig. 1.—Diagram of lantern polariscope.

with the old elbow form of polariscope, an arrangement is used in which the rays are reflected forwards again after polarization, as shown in *Fig. 1.*, in which *A* is the source of light; *B B* condensing lenses for parallelizing the light rays; *C* the bundle of glasses for polarizing by reflection at the angle of 57°; *D* a silvered mirror; *E* a convex lens for bringing the light rays to a focus within the small Nicol prism used as an analyzer. The stage is just in front of *E*, and is not nearly as convenient for many purposes as a horizontal stage would be.

For my own use, and to meet certain special requirements, I recently constructed a lantern polariscope in which the

position of the reflecting surfaces *C* and *D* is so altered as to bring the stage into a horizontal position, and at the same time that portion of the light transmitted by the glass bundle is utilized for ordinary projection purposes, and ordinary slides or other optical demonstrations can be interspersed with or superposed upon the polariscopic projections. This

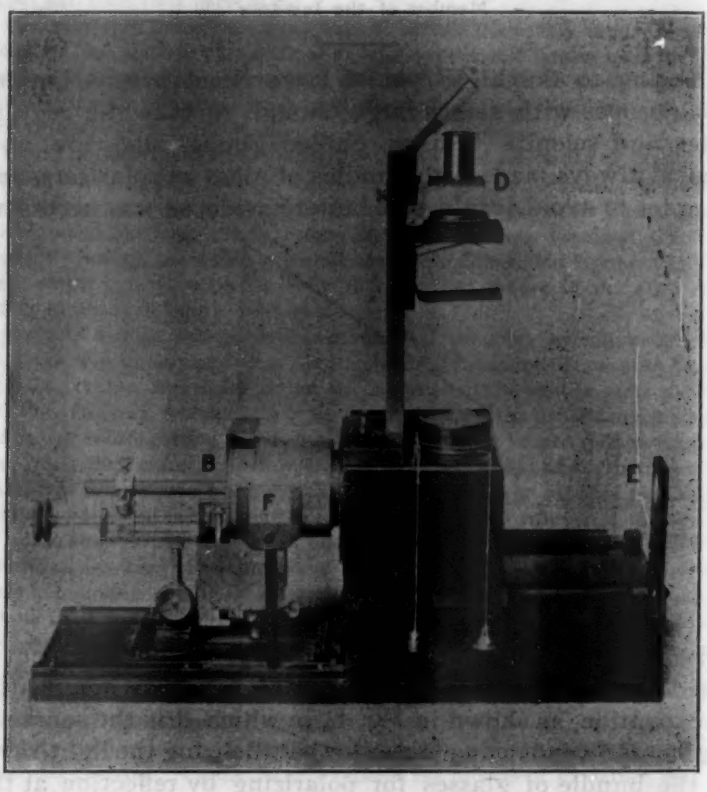


FIG. 2.—Ives' lantern polariscope.

instrument having attracted some attention and been favorably commented upon when used at recent meetings of the Institute, I have been induced to furnish the following description for publication:

The general disposition and appearance of the instrument is shown in *Fig.* 2, in which *A* is a light wooden platform; *B*

is a "right angle" hand-feed electric lamp, as made by the McIntosh Company, of Chicago; *C* is a light, rectangular wooden box, with hinged lid, containing the polarizing and silvered reflectors, and carrying the condensers and stages. *D* is the polariscope objective, analyzer and right angle reflector, and *E* is the objective for ordinary lantern slide projection; *F* is a small ground glass upon which is projected an image of the electric arc, through a "pin-hole" opening in the sheet-iron hood.

Fig. 3 is a horizontal section of the box *C* of *Fig. 2*. *A A* are the condensers for parallelizing the rays from the source

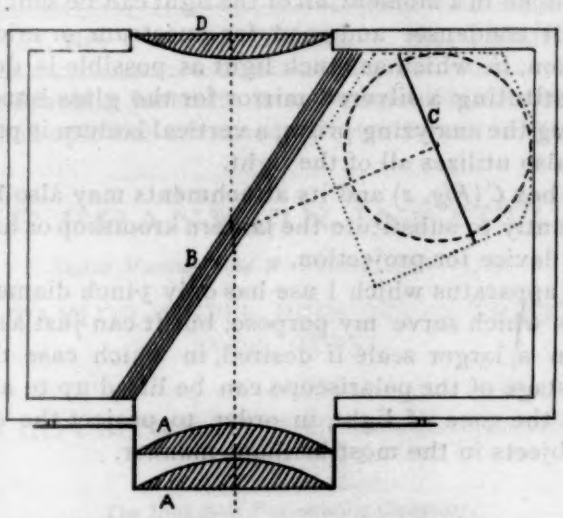


FIG. 3.—Plan of Ives' lantern polariscope.

of light. This condenser system should be perfectly aplanatic for the best results, but the combination indicated in the plan answers very well with the electric arc light. *B* is the polarizing bundle, made up in my own instrument of twelve sheets of special extra thin polished plate glass. The twelve sheets make a bundle $\frac{3}{8}$ of an inch thick. *C* is a silvered mirror so inclined in the horizontal plane as to project the polarized rays vertically upwards through a condensing lens, which cones them into the objective and analyzing prism. *D* is the condensing lens for coning the

direct rays into the objective for ordinary projection. The objective which I use is a single plano-convex achromatic lens, which is perfectly efficient with the electric arc light if the condenser is of suitable focus. It is attached to the box in which the analyzer combination is packed, and which slides within the lantern base to focus. Both objectives are supplied with a simple form of shutter.

The objective for polariscopic projection is of somewhat longer focus than that for ordinary projection, giving a smaller disk, and so making the illumination of the two disks about equal. By removing the glass bundle, which can be done in a moment, all of the light can be sent through the front condenser and used for spectrum or microscope projection, in which as much light as possible is desirable. By substituting a silvered mirror for the glass bundle, and removing the analyzing prism, a vertical lantern is produced, which also utilizes all of the light.

The box *C* (*Fig. 2*) and its attachments may also be lifted off instantly to substitute the lantern kromskop or any other special device for projection.

The apparatus which I use has only 3-inch diameter condensers, which serve my purpose, but it can just as well be built on a larger scale if desired, in which case the horizontal stage of the polariscope can be lifted up to a smaller part of the cone of light, in order to project the ordinary sized objects in the most brilliant manner.